TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA

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OBITUARIES

ARTHUR LEWIS HALL

At the time of his death on August 13, 1955, in his eighty-fourth year, Arthur Lewis Hall was the oldest Fellow of the Royal Society of South Africa. He became a member of the South African Philosophical Society in 1904 and was elected in 1909 as one of the first Fellows of the newly chartered Royal Society which succeeded the Philosophical Society with headquarters in Cape Town.

After receiving his formal education in Germany, at Bristol, and at Caius College, Cambridge—where he won the Harkness Scholarship in Geology—Hall took up an appointment as Geologist to the Geological Survey of the Transvaal early in 1903, under the directorship of H. Kynaston, together with E. T. Mellor. Twenty-nine years later, in 1932, he retired from the Government service having, since 1916, occupied the post of Assistant Director of the Geological Survey of the Union of South Africa. During these years of service he ranged widely among the rocks of the Transvaal, excluding from detailed investigation only those of the Witwatersrand and Karroo systems. A meticulous observer, both in the field and at the microscope, he amassed a wealth of facts; a fluent writer, he found little trouble in assembling these accumulated facts in a readable form and in presenting the conclusions which he had drawn from their study.

His interest in the acquisition of data led to the production of the *Bibliography of South African Geology*. The basis for this was the 'Catalogue of Printed Books, Maps, etc. on South African Geology' prepared by Dr. M. Wilman and printed in the *Transactions of the South African Philosophical Society* in 1905, to which work Hall paid tribute in his first volume. This first volume included literature published to the end of 1920, and was followed by a Subject Index as a companion volume. At appropriate intervals there appeared an Author's Index for the period 1921–5, one for the period 1926–30, another for the period 1931–5, and a Subject Index covering these three. The last two were prepared for the Geological Survey after Hall's retirement into private life; but the material was freely given by him to the Geological Survey. Similarly, after his retirement, he compiled his *Analyses of Rocks, Minerals, Ores, Coal, Soils and Waters from Southern Africa*. This was published by the Geological Survey in 1938 and tabulates 5,621 chemical analyses of located samples with references to the publication medium of each analysis.

However great the debt of gratitude owed by geologists for these 'spare-time results' of his assiduous bibliographic research, Hall's fame as a geologist rests fundamentally upon his stratigraphic and petrologic studies which resulted in the production of such basic publications as those on the Murchison Range area, the Barberton mountain-land, and the Bushveld Complex of the Transvaal. These, together with his work conjointly with Molengraaff on the history of the Vredefort dome, gave him a world-wide reputation and brought to South Africa eager inquirers of outstanding merit to see for themselves, in his company, the phenomena which he had so well described. These fundamental studies were supplemented, from time to time, by others of a more 'practical' nature dealing with the modes of occurrence and origin of several important mineral substances such as mica, corundum, and

asbestos. Although some of Hall's views on rock and mineral origins have been questioned by other workers, many of them have stood the test of the most searching scrutiny; the facts that he recorded have never been disputed.

In 1926 the International Geological Congress assembled in Spain and Hall attended as a Government delegate. There he proffered an official invitation to the Congress to hold its subsequent meeting, in 1929, in South Africa. The invitation was accepted and Hall was nominated by the Union Government as Secretary-General for the meeting. Exercising his outstanding powers of detailed organization he, with Rogers as President-elect, was responsible for making the Congress and its associated excursions an unqualified success and in stimulating interest in South African geology among the hundreds of overseas visitors and delegates.

A further aspect of Hall's many-sided interests in geological science is to be seen in the geological museums in Pretoria and Cape Town. When the large gallery in Pretoria became available for display purposes after the end of World War I, Hall became responsible for its equipment and arrangement. At the same time, he provided large numbers of trimmed and labelled rock specimens to augment the display in the South African Museum.

The value of his work was acknowledged by several awards. The Geological Society of South Africa elected him as its President for the year 1913–14 and, when the Draper Memorial Medal was instituted, made Hall its first recipient; he was also one of the few who have been made Honorary Members of that Society. A Fellow of the Geological Society of London since 1900, he was awarded its Murchison Medal in 1930. The Geological Society of America elected him to Corresponding Membership in 1934. From his own University of Cambridge he obtained the Sc.D. He was elected a Fellow of the Royal Society of London.

Hall was an intensely human character, interested in many facets of life. Although it would be difficult to state which of his interests afforded him the greatest pleasure, there can be no doubt that music stood very high in the list. Possessed of considerable executive powers as a violinist, he had a wide knowledge of the works of the classical and romantic composers and maintained a fine collection of scores and instrumental parts. Even in his latter years, when he was unable to remain a player, he was assiduous in organizing gatherings of his musical friends and in guiding them in the performance of the trios, quartets, and orchestral works that he knew and loved so well.

Ill-health and near blindness dogged the last few years of Hall's life but he never bewailed his lot. The deaths of two of his sons, both professional scientists, in their prime of life and in quick succession saddened his last years. He is survived by his widow, one son and one daughter, and by a host of friends who were endeared to him by his kindly and understanding humanity.

S. H. H.

* * *

THOMAS BENJAMIN DAVIE

Dr. Thomas Benjamin Davie, Principal and Vice Chancellor of the University of Cape Town, died in London on December 13, 1955, at the age of 60. He had devoted his whole working life to education, either in South Africa, the country of his birth, or in England. The example which he set, and his achievements, have made him one of the most outstanding academic figures in South Africa.

Dr. Davie was born in Prieska in the Cape Province on November 23, 1895. He chose first a career in primary education, preparing himself for it by taking a B.A. degree at the Victoria College in 1914, and a First Class Professional Teacher's certificate in 1916. He then taught in schools in the Transvaal and Orange Free

State. At the age of 28, however, he decided to change his career to one in Medicine. He chose Liverpool University for his studies and in 1924 started what was to be a long and distinguished association with that University. As a student he was outstanding—he gained many distinctions and was awarded his degree with first-class honours. His intellectual power and capacity for work soon brought him other rewards. In 1929 he was appointed Lecturer in the Department of Pathology; six years later he moved to Bristol to his first Chair, and in 1938 he returned to the George Holt Chair of Pathology in Liverpool. The Fellowship of the Royal College of Physicians was awarded him in 1940. In 1939 the war brought with it many new problems for the incumbent of the Chair of Pathology, amongst them the organization of a Regional Blood Transfusion service, and in dealing with these Dr. Davie showed his outstanding ability as organizer and administrator. This capacity he was to develop further when in 1945 he was appointed the first full-time Dean of the Faculty of Medicine. He rendered outstanding service to his University in this capacity until he moved to the Principalship of the University of Cape Town three years later. His first love was for teaching and research; he soon established a reputation as a teacher of Pathology of both undergraduate and postgraduate students while the twenty-three publications issued during the course of twelve years, bear witness to his activity in research. However, his sense of duty forced him to relinquish these to enable him to devote himself to the service of his University in fields of organization and administration in which his assistance was most needed.

The universities in South Africa will always remain grateful that in 1948 Dr. Davie responded to the call to return to the country of his birth. As Principal of the oldest and one of the largest universities in South Africa, he came to show his true stature. With his educational background, his knowledge both of the Arts and Sciences, his clear incisive brain and indefatigable energy, his friendliness and approachability, his administrative ability and strong personality, he fitted ideally into the leadership of a large university. He soon became known as the champion of university affairs who fought vigorously the cause of his and other universities in South Africa during a time when the problems confronting them were particularly difficult. He upheld fearlessly the principles of university freedom.

Dr. Davie's counsel was eagerly sought by many public and private institutions and organizations. He was a member of the Council for Scientific and Industrial Research, chairman of its Medical and Dental Research Committee, and member of the National Council for Social Research; he was a representative of the Committee of Principals on the Advisory Committee to the Minister of Education, Arts and Science, and he served on the controlling boards of many other organizations. On the many university committees on which he served he was an inspiration to his colleagues. There could be no doubt that Dr. Davie was one of those exceptional people who could enjoy and who had an enthusiasm for committee work—an enthusiasm that grew out of his administrative ability and his gift of understanding a problem and being able to clarify it for others.

Great as have been Dr. Davie's achievements, they are greater still when viewed with the knowledge that for all the years of his Principalship he suffered from a crippling illness. In spite of pain and physical disability he carried out to the full his official duties and found time for many outside activities. It was partly through his public statements at functions outside the University that he became such an important public figure, one whose opinions still are valued by many, whether they agreed with him or not.

Despite his many responsibilities, he found time for a wide range of cultural pursuits and, because he was one of the most approachable and unassuming of men, he was always ready to give guidance to any member of the student body or staff who sought his counsel. In the hospitable atmosphere of 'Glenara', his official

residence, he and his wife, Mrs. Vera Davie, delighted often in bringing together his colleagues and visitors to the University, not only for pleasure but as part of their work of building, stimulating and inspiring a university team. Every one of the many scholars, educationalists and industrialists who were guests at 'Glenara' will have reason to remember the characteristic South African hospitality which they received there. All will have been impressed, too, as were Dr. Davie's colleagues at his University, by the unselfish devotion of Mrs. Davie to her husband and the University. Mrs. Davie played her part, and it was no insignificant one, in establishing the outstanding record of her husband and the post he occupied.

Dr. Davie's work has been recognized by the award of an honorary degree by the University of Cambridge, and by his election to the Fellowship of the Royal Society of South Africa in 1948. He was to have received honorary doctorates from Liverpool University and the University of Oxford during his last visit to the United Kingdom, where he had gone to represent his University at the Installation of the Queen Mother as Chancellor of the University of London. Great as are these honours, they could be but small reward for what he had achieved. South Africa, and its universities in particular, will continue to owe Dr. Davie a debt of gratitude which cannot be repaid, and his name will remain a living and honoured one for many years to come.

M. V. D. E.

* * *

CLARENCE VAN RIET LOWE

Clarence van Riet Lowe, Director of the South African Archaeological Survey and Professor of Archaeology at the University of the Witwatersrand, died on the morning of June 17, 1956, following a minor operation. It is here only possible to outline briefly some of his major achievements in a variety of fields.

Born at Aliwal North on November 4, 1894, he was educated at Zastron, Grey College, Bloemfontein, and the South African College, Cape Town. In 1914 he joined the Duke of Edinburgh's Own Rifles, later transferring to the South African Field Artillery, and was finally posted as an officer to the Royal Horse Artillery with whom he served in Palestine, Italy, France and England.

After the war he returned to finish his course (B.Sc. in Civil Engineering) at the University of Cape Town, and was appointed as Assistant Engineer to the Public Works Department at Pretoria and in Natal. In 1922 he married Miss Iris E. Kelly at Cape Town, prior to transferring to a post as Resident Engineer in the Knysna District. Here his interest in archaeology found scope and he published his first brief paper in 1922. In the following year he became Assistant Engineer in the Orange Free State, and during five years was able to locate and collect material from some 300 prehistoric sites. It was his association and constant correspondence with the University of Cape Town and the South African Museum at this time which was to lay the foundations for his future career.

From 1928 onwards his work took him to a number of areas in the Transvaal and the Cape Province, and in 1931 he was made Chief Engineer at the Public Works Department, Pretoria. In the same year he was elected President of Section E of the South African Association for the Advancement of Science, and acted as their delegate to the British Association Centenary Meeting in London.

In 1934 he was elected a Fellow of the Royal Society of South Africa. In the following year he was made first Director of the Bureau of Archaeology, created at the instigation of the Rt. Hon. Field-Marshal J. C. Smuts, and was made Professor of Archaeology at the University of the Witwatersrand. He became a member of

the Commission for the Preservation of Natural and Historical Monuments, Relics and Antiques, and represented South Africa on the International Historical Monuments Commission, League of Nations, Geneva. He was awarded the King's Jubilee Medal.

In 1937 he was President of the South African Museums Association and undertook research in a variety of areas from Cairo to Southern Rhodesia. In the following year he was accorded the D.Sc. of the University of Cape Town for his work in archaeology.

He collaborated with E. J. Wayland in research in Uganda in 1939. With the outbreak of war he returned to the Artillery and was made Major commanding the 91st (Witwatersrand University Training Corps) Battery, 31st (N.V.B.) Field Regiment (V.) South African Artillery.

He was awarded the South African Medal in 1943. In the following year the Bureau of Archaeology was raised to the status of the Archaeological Survey. He remained as Director until his retirement in 1954. During this period he attended as an official delegate the first and third Pan-African Congresses (Nairobi 1947, Livingstone 1955). He was elected Vice-President of the South African Association for the Advancement of Science for 1948 and President in 1949, and President of the South African Archaeological Society in 1952. He retired as Director of the Survey in 1954 but retained his Professorship at the University of the Witwatersrand.

In 1955 he lectured for a term at the University of Cape Town and had intended to initiate a teaching course in archaeology at the University of the Witwatersrand.

Professor van Riet Lowe's chief contributions to science lay in his study of the Earlier Stone Age, the most remote phases of man's story. This era he virtually made his own through his practical application of an intimate knowledge of the history and deposits of our South African drainage system. But his interests were by no means confined to this era and area. He collaborated with other field-workers in Uganda, Tanganyika and the Rhodesias, and in the Vaal and Little Caledon River basins in search of evidence of climatic changes. His excellent draftsmanship was skilfully employed in copying prehistoric art and in drawing stone implements. As a lecturer he was clear and convincing, able to enthrall his audience and to inspire them in a way rare in a field-worker. He set himself the task of building up the finest collection of prehistoric and historic beads in southern Africa, realizing the potential value of such a series in dating past culture contacts. His work in a number of fields was published in over one hundred and fifty scientific papers and reports, either alone or in collaboration. A high proportion of these are of outstanding merit.

In all, he was a man of wide and keen interests, whose vital personality impressed itself vigorously on a wide circle of friends and associates from all parts of the world. His death removes an outstanding figure; a man who had achieved merited success in civil engineering, in prehistoric archaeology, in the military field, in the organization of the Natural and Historical Monuments Commission and of the Archaeological Survey.

A. J. H. G.

TRANSACTIONS
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PRESIDENTIAL ADDRESS

CO-OPERATION IN SCIENCE AND TECHNOLOGY IN AFRICA SOUTH OF THE SAHARA

By S. H. Haughton

(Read April 17, 1956)

The opening sentence of the second paragraph of our Constitution reads 'The Aim of the Society shall be the furtherance of Science'. To achieve this aim, we are urged to hold regular meetings, to publish an Annual Volume, and to maintain a Library of Scientific value.

Throughout its life, the Society has maintained these methods of achieving its aim. It has held regular meetings—at some of which but a few of its more enthusiastic Members and Fellows have been present; it has published its *Transactions*; and it has maintained a Library. Lest, however, we should incline to complacency regarding the results of our corporative efforts, it might be wise for us to pause from time to time to consider the meaning of what has been set out for us as our 'Aim'—the 'furtherance of Science'.

Our Society is the lineal descendant of the South African Philosophical Society. That Society was constituted on June 22, 1877, when its objects were declared to be 'To promote original research and record its results, especially as connected with the natural history, physical condition, history, geography, statistics, industrial resources, languages, and productions of South Africa'. This specificity of subjects is not exclusive; the field was left open for the promotion of research and the recording of its results in other branches of philosophy—a word that became 'Science' in our own Constitution.

In the years that have elapsed since 1877, the terms used in that year have tended to become obsolete and to be replaced by others each of which is considered to be the name of a defined 'science'. Specialization—and, in these latter days, ultra-specialization—has subdivided the order of Scientist into sub-orders such as Zoologist or Botanist, and each of these into a plethora of families, genera and species;

so that a modern research worker or group of research workers might find a rightful classification as:

Order:	Scientist
Sub-order:	Zoologist
Family:	Vertebrate Zoologist
Genus:	Ornithologist

In the same way, we can no longer speak of the study of 'physical condition'. We have become students of geology, or of meteorology, or of astronomy, or of hydrology, or of some one or other of the allied 'sciences'; and our students of geology tend to specialize as petrologists, or as mineralogists, or as stratigraphers, or as economic geologists, and so on.

With the ever-increasing tempo of extensive and intensive inquiry into the phenomena displayed by the world in which we live and the animate world of which we are a part, such scission has been inevitable. In South Africa, as elsewhere, devotees of a particular branch of Science tended to band themselves together into a Society with the object of furthering the study of their particular field through the media of meetings and of publication; many of these societies have had a long and honourable career and the results of their efforts, as evinced by their periodical publications, are of value and of high standard. Moreover, because of the geographical and other conditions which are a feature of the South African picture, societies other than our own have been formed and are flourishing, whose fields are intended to embrace Science in the same sense as that given to the word in our own Constitution. The total membership of the societies which exist in our country for the promotion and recording of research in one or other of the fields envisaged by the pioneers who founded the Philosophical Society is an impressive figure; but it is greater than the number of individuals who form the members, since some of these spread their activities, their interests and their substance in support of two or more of the organizations. An examination of the lists of our own Fellows and Members would show that all or nearly all of these individuals support at least one other South African scientific society in addition to our own which, because of its age, may be looked upon as the parent of the younger bodies.

Consideration of the more recent history of our Society in the light of the activities of others in our country leads one to pose one or two fundamental queries. Is the Society maintaining the position in the world of scientific inquiry which it, and its forerunner, once held? As a body corporate, are the advancing years of its life being accompanied by a diminution of vitality? In view of the existence of active organizations which cater for the specialist, is there an essential reason for the continued existence of the Royal Society of South Africa? Questions such as these demand examination.

Although posed separately, the questions are inter-related. The 'furtherance of Science', for which we exist, can be effected in a number of ways. From our inception, we have published papers of a high standard containing new information and setting forth ideas—either new ideas or old ones in a fresh garb—and we have refused to accept for publication others which, in our opinion, were below the required standard.

We have, particularly in recent years, arranged for distinguished men and women of science to lecture on the subjects in which they were expert to those who were able to be in Cape Town at the appropriate times; but we have not been able to make the substance of those lectures available to people elsewhere. In pre-Union days, the Philosophical Society maintained fairly close relationships with the Cape Government and its advice was sought in matters connected with the advancement of scientific knowledge. There has been, since 1877, a history, intermittent though it may be, of the 'promotion of original research' and of advice tendered to and accepted by those who held the power of granting financial help to such research. It would seem that, under present circumstances, although among our Fellows and Members we include a very large proportion of the leading scientists of the country, as a Society we are rarely called upon to express our views upon some suggested development in the promotion of scientific investigation. To put it bluntly, there is an increasing tendency in some minds to consider our Society as being a body floating quietly and sedately in a backwater cut off from the rapidly moving main stream of scientific progress, however much its individual members are capable of maintaining their positions in that stream.

Whether this suggestion be true or false, we maintain our interest in the 'furtherance of Science'; and it is of interest to consider the important events associated with the stimulation of scientific research which have occurred in Africa during the past few years, under the aegis of the governments in association.

Partly as a result of the discussions which took place at the African Scientific Congress in Johannesburg in 1949, and in accordance with an agreement to achieve closer co-operation in technical and scientific matters which they had reached in 1948, six governments operating within Africa south of the Sahara—viz. Belgium, France, Portugal, Southern Rhodesia, the Union of South Africa, and the United Kingdom—created two organizations in 1950. These were known as the Commission for Technical Co-operation (C.C.T.A.) and the Scientific Council for Africa (C.S.A.), both bodies having as their field of action Africa south of the Sahara. Operating initially as separate entities, each with its own Secretary-General and its own budget, these two organizations have now been fused, with governmental approval, into one, in which the C.S.A. retains its identity as the independent advisory body on scientific matters empowered to study and initiate co-operation in the domain of science within this vast area. The six member governments (that of the Federation of Rhodesia and Nyasaland now having taken the seat originally occupied by Southern Rhodesia) thus have an organism—which is not a bureaucracy—through which they can be advised on social, technical and scientific matters which are of common interest and on which collaborative effort is both desirable and possible. For the financial maintenance of this organism the member governments make agreed annual contributions.

The fundamental objective of the member Governments is the optimum utilization of technical resources and scientific knowledge for the advancement of Africa south of the Sahara and the improvement of the standard of living of its peoples. The attainment of such an objective demands therefore an assessment of the resources

and knowledge available and a study of those fields in which further knowledge and further resources must be sought. Within each of the countries concerned there are specialists in one or more of the numerous subjects that collectively comprise Science; the first step taken by member governments was to arrange for workers in a particular field to meet in conference and to recommend what steps should be taken to attain, at least in part, the desired end. In recommending the subjects to which conferences should be devoted and in advising the conjoined governments on the application of the results of such conferences, the Scientific Council for Africa plays a vital and constructive part.

Without entering into too great detail, let us look at some of the results which have been obtained and the fields that have been preliminarily surveyed in the seven years since the governments first agreed on co-operative effort.

The first conference called was the Inter-African Conference on Soils at Goma in 1948. As a result of its recommendations, member governments have established an Inter-African Soils Bureau (headquarters in Paris) and an Inter-African Pedological Service (at Yangambi, Belgian Congo) and have encouraged the creation of four regional committees (one in Southern Africa, one in Central Africa, one in West Africa, and one in East Africa). The Bureau is primarily an organization for the dissemination of information and has a Council of Administration which also functions as a technical consultative committee. It takes cognizance of matters concerned with the problems of degradation, utilization and conservation of the soil, pasturage, indigenous rural economy, and those connected with the mechanization of agriculture. On these last two subjects specialist conferences have also been held. The Pedological Service is an investigatory organization concerning itself with the methods of soil analysis, pedogenetic studies, black tropical clay soils, and the preparation of soils maps of Africa. In these and kindred matters the role of the regional committees in the study of techniques and of soil management, each in its own area, is of prime importance.

Allied to the subject of soil utilization is that of sylviculture. An Inter-African Forestry Conference was held in 1951; a second will probably be held in 1956 and will concern itself principally with the question of the organization of permanent liaison between the various African forestry services.

The African Scientific Conference of 1949 drew attention to the direct or indirect effect of meteorological phenomena on many activities and recommended that steps should be taken for the preparation and publication of a climatological atlas for Africa and for the compilation of a meteorological bibliography for the continent. After consideration of these recommendations by the World Meteorological Organization and by a specially constituted Working Party, member governments of C.C.T.A. agreed to accept the preparation and publication of the suggested atlas as 'Joint Project No. 1' and to provide a sum of £12,500 for it. The preparation of the atlas was entrusted to Dr. S. P. Jackson of the University of the Witwatersrand. He is guided in the task by a Committee of specialists acting under the aegis of the C.S.A. and is supported in his choice of scales for the atlas by C.C.T.A.'s Consultative Committee on Maps and Topographical Surveys. Being accredited as editor by

member Governments, Dr. Jackson has been able to effect the closest collaboration with the official organizations in the African territories (which, incidentally, include Madagascar and the islands of the western Indian Ocean) and to obtain from them necessary relevant data.

Recognizing the desirability for close co-operation in geological studies and the investigation of mineral deposits throughout the sub-continent, the Conference of 1949 suggested that governments should consider the establishment of an organization to disseminate information on matters of common interest in these fields and to act as a co-ordinating centre in geological research matters. After consideration of the suggestion by the Scientific Council, the Commission approved of the formation of three regional committees for geology and of the appointment of an Inter-African Scientific Correspondent whose functions should be liaison, informatory, and advisory. These arrangements came into force in the latter part of 1954. Meetings of the regional committees have been held and have provided opportunities for fruitful discussion and collaboration; while an information service has maintained a regular supply of abstracts, has compiled bibliographies and other lists, and has kept closely in touch with the operations of the various geological organizations throughout the area. Through the committees and the work of the Correspondent it is hoped, *inter alia*, to promote the more frequent visits by geologists to territories other than their own, to encourage mutual assistance, and to arrange for collaboration in specialized studies.

Since the close of the 1949 Conference, the C.S.A. has considered at several meetings the desirability of inaugurating co-operative long-term hydrological research leading to an assessment of the nature, quantity and utilization of water resources. A meeting of specialists in the 'Use of Irrigation Water and Drainage in Agriculture', held under its auspices late in 1955, stressed the importance of hydrological studies and observation and that of a wide application of ecological methods in all extensive hydrological development projects, calling for close co-operation between specialists in the fields of soils, climate, vegetation, and animal biology. The Scientific Council has recommended the convening of a meeting of experts from the various parts of Africa to consider means of undertaking co-operative studies of the water cycle in Africa and of the natural geographical units represented by the various hydrographic basins.

The first Inter-African Conference on Epizootic Diseases, held at Nairobi in 1948, confined its discussions to the subject of rinderpest and recommended the establishment of an organization for the exchange of information on this animal scourge and of a scientific committee to deal with the subject. C.C.T.A., however, decided to extend the functions suggested for such an organization and inaugurated, at the end of 1951, an Inter-African Bureau for Epizootic Diseases, whose scope would include the principal infectious and contagious diseases of cattle in Africa. Associated with the programme of work of this Bureau is an Advisory Committee on Epizootic Diseases whose principal task is to advise C.C.T.A. governments on practical measures of control of, and research into, the main diseases of animals. The research envisaged includes studies of stock diseases, viral, bacterial, and protozoan, among wild rumi-

nants at an inter-African level, beginning in a single ecologic unit and financed jointly by member governments. Realizing, however, that measures against epizootic diseases are but one aspect of the whole problem of increasing supplies of animal protein and thus raising the standard of living of the population, the advisers of C.C.T.A. consider it desirable that the Bureau for Epizootic Diseases should include animal breeding and animal husbandry in its programme of information and advice.

The problem of the supply of animal proteins involves the study of fish supplies. The member governments of C.C.T.A. have applied a systematic policy to the development and co-operative studies of inland fisheries, and have arranged for regional conferences on the technical and scientific aspects of maritime fisheries—one for the Atlantic side of the area in 1957 and one for the Indian Ocean side in 1958. On the scientific side these conferences will deal with the problems of physical oceanography and of marine biology—problems wide enough to justify a whole series of specialist consultations.

Linked with the question of the supply of more and better foodstuffs, and with all that this implies for the welfare of Africa's people, is the study and the dissemination of knowledge of pests, other than those of which mention has already been made. The study and control of locusts has, of course, been an international undertaking for a number of years and the C.C.T.A. governments partake in the support of the organizations which operate in this field. In 1955 there was convened by C.C.T.A. a conference of specialists to discuss the problems raised by the depredations of the various forms of the finch *Quelea*. This conference resulted in co-ordinated action being initiated for control, based on a proper study of all the biological and ecological factors affecting the subject. As Professor Monod stated in his opening speech at the meeting, 'Basic research is indispensable. There is no possible short cut in natural science and it is only too well known how dangerous it is to interfere in a disorderly, blind, or merely premature manner with the natural precarious balance that inconsiderate human action may sometimes irretrievably jeopardize.' He stressed the fact that only study of the bird itself would lead to new, more efficient, and cheaper protection against the damage that it causes. Plant pests and their distribution, too, have come under consideration and active steps have been taken to control their spread. A Phytosanitary Convention has been signed and a Phytosanitary Commission with a Scientific Secretary is on the point of commencing operations in an attempt to co-ordinate legislative and quarantine control based on a scientific knowledge of plant pests and the diseases which affect plants. Had such control been effective in the past, it is possible that the introduction and spread of the water-hyacinth, *Eichornia*, might have been halted before it proved itself to be the menace that it is in many parts of Africa.

Co-operative efforts in the fields that have been briefly outlined here are aimed at increasing the welfare of the human inhabitants of the territories for which the governments concerned have responsibility. These therefore have interested themselves in seeking to know the conditions which are most favourable to the full development of the populations under African conditions, a development that demands not only the taking of measures against endemic and epidemic diseases and research into

the nutritional needs of population groups but also the study of social problems and that of productivity. Much, of course, has been and is being done by individual governments in Africa in the study of and research upon problems of curative and preventive health measures, of nutrition, and of social and labour matters; operating as C.C.T.A., they endeavour to share the results of such studies and research for the benefit of all and to arrange for the interchange of information among their various official medical and other services.

In the field of public health and medicine, the C.C.T.A. governments support a Bureau for Tsetse and Trypanosomiasis (B.P.I.T.T.) and a Scientific Committee for research on Trypanosomiasis formed of experts representing the governments, who hold regular meetings. They have set up Panels of Experts on other diseases common in Africa, as well as a Panel of Correspondents on Nutrition which operates continuously between the periodic C.C.T.A. Conferences on Nutrition. In acting thus, the governments have not endeavoured to duplicate the work done in these spheres by Specialized Agencies of the United Nations, such as the World Health Organization and the Food and Agricultural Organization, with whom appropriate C.C.T.A. Bureaux and Panels work in harmony, but to confine themselves to the various problems at a strictly African level.

Realizing that health depends as much on social factors as on medical factors, the C.C.T.A. governments have agreed on co-operative investigations and continuing studies of the former as they affect the indigenous populations. Conferences on Rural Welfare, on Education, on Co-operative Societies, on Technical and Agricultural Training, on Juvenile Delinquency, and on Housing have served to focus attention on the methods and plans adopted by individual governments in these fields, have provided in each case a forum for discussion by experts and for interchange of views, and have led to the formulation of recommendations for consideration by the responsible authorities. In the case of Housing Research a permanent Committee has been established, whose secretariat is at present being provided by the Union of South Africa. This Committee is intended to develop collaboration in housing research and in the utilization of the fruits of such research, to consider and co-ordinate expert advice on the solution of housing problems, and to recommend to governments steps to improve housing practice.

An Inter-African Labour Institute was set up in 1952 to act as a permanent liaison organization between labour officers and as a centre of information regarding labour legislation in Africa and studies of a general nature. Four Inter-African Labour Conferences have been held under C.C.T.A. auspices between 1950 and 1955, at which matters of common interest have been discussed objectively.

The remaining group of subjects which appeared to the C.C.T.A. governments to be capable of being treated co-operatively is that known as the Social Sciences. An Inter-African Committee met at the end of 1954 to make plans for a large-scale Conference of experts, which took place in August of the next year. The Conference had as its objective the establishment of 'An inventory of existing knowledge in the various fields of research having a bearing on social science and connected with the economic development of Africa south of the Sahara, in order to determine existing

gaps in such knowledge.' The field is wide, ranging from physical anthropology to administration methods. Nevertheless, experts from all sections of the Conference agreed that there was a lack of elementary data on basic methods and that priority should be given to co-ordinated research that could increase knowledge and lead to the adoption of comparable methods and modes of expression.

A very recent meeting of the Committee on Social Sciences stressed the need for speeding up the preparation of population distribution maps, and recommended the exchange of information on migration surveys. It also recommended the establishment of a documentation centre for physical anthropology, the establishment of a scientific centre for the collection of aptitude tests, and the setting up of arrangements for the collecting and dissemination of information on work in progress or projected in a number of disciplines that are comprised within the broad field of social science.

In addition to providing the funds for the maintenance of the C.C.T.A./C.S.A. Joint Secretariat and of the various organizations which operate under its aegis as well as for the holding of conferences, symposia, and committee meetings on the invitation of a Host government, the member governments have co-operatively instituted two funds for the furtherance of their objectives. One of these is known as the Inter-African Research Fund, designed to provide moneys for what are called 'Joint Projects'. The first of these to be accepted is the preparation and publication of the Climatological Atlas for Africa, to which reference has already been made. The second is the preparation and publication of a book outlining the contribution of science to the development of Africa. This work is being undertaken by Dr. E. B. Worthington, whose earlier 'Science in Africa' resulted from Lord Hailey's survey. The other conjoint organization is the Inter-African Foundation for the Exchange of Scientists and Technicians, whose object is implicit in its title.

This is a brief and inadequate review of the matters that have come within the purview of an inter-governmental organization within a period of less than a decade and of the positive action that has resulted from the considered recommendations of groups of scientists and technicians, after they have passed through the filter provided by the Scientific Council for Africa. Two facts of interest stand out clearly. The first is the willingness of the governments concerned to agree to the pooling of data in scientific and technical subjects and to the taking of steps aimed at facilitating the interchange of the results of research work obtained in the individual territories. The second is the increasing degree to which governments are looking to the scientists and technicians to furnish them with the basic information which is essential to the formulation of policies designed to develop the resources of Africa south of the Sahara and to bring about an amelioration of the lot of its inhabitants.

As scientists, we can welcome wholeheartedly the spirit which has animated the governments concerned in this co-operation on the African plane; as a South African body we can rejoice that our country is—as it is equipped to do—playing a prominent part in the conjoint actions which have been taken thus far. But positive actions in the construction of developmental programmes and the formulation of policies governing such programmes are dependent on the provision of scientific data. These must normally be obtained by the scientists and technicians of each individual country

who ought therefore not only to work in co-operation with those of the other countries but also freely to pool their findings among themselves. We, as a Society pledged to the furtherance of Science, can usefully play a part in supporting the accumulation, dissemination and exchange of scientific data and in stressing the need for concerted action by workers in allied fields. Handicapped as we are financially, we cannot expect or be expected to make any spectacular contribution either to the support of actual research work or to the publication of research results beyond that which has been possible hitherto. We can and should, however, make it known that the will to co-operate in the scientific investigations envisaged for Africa south of the Sahara is ours, and that the extent of our co-operation is merely a function of our resources.

These resources on the human side could be enlarged by an increase in our membership—we have not, at present, as members all those workers in southern Africa who possess the qualifications which our Statutes demand. But even a substantial increase in our membership would not provide us with the financial means to expand appreciably the volume of published papers that form our permanent contribution to the furtherance of science. During the past few years we have been able to publish certain papers of importance only with monetary support from the Council for Scientific and Industrial Research, for which support we have been grateful. Nevertheless, I feel that to a certain extent this is support 'with strings attached' in that the final decision regarding the publication of a specific paper rests with the C.S.I.R. and not with our own Council. It seems to me that the Royal Society of South Africa might well be thought capable of deciding on the scientific value of papers submitted to it for publication and might, without danger, be entrusted with a larger governmental grant-in-aid than that which it now receives, in order that it could properly fulfil its function of disseminating important information through the medium of its *Transactions*.

There would seem to be reason for considering the type of paper that these *Transactions* should include. Science, as envisaged by the Scientific Council for Africa, ranges widely from, let us say, astronomy to the fundamentals of Native administration. Some of its many subdivisions are catered for in our country by the specialist societies, and specialist information tends naturally to be laid before and made available by these societies. But isolated contributions to knowledge in one branch of Science can often be synthesized with other contributions in that branch or in another branch; indeed, it is often only by such synthesis that the maximum value of isolated data can be obtained. The importance of the specialist conferences and symposia that are organized under the aegis of C.C.T.A. lies both in the opportunities that they afford for comparison and synthesis of the information held by individual specialist workers in the various territories of a region or of the whole sub-continent and in the recommendations for governmental action that may arise as the result of co-operative and co-ordinated consideration of the known facts. In a number of cases co-ordination of the available data has shown only too clearly the voids that exist in the knowledge of a particular subject; such voids have been charted, and governments have been urged to take steps to fill them.

While it would be unrealistic and impractical to suggest that our Society could suddenly become an indispensable part of the machine that is being elaborated for the development of Africa south of the Sahara and the improvement of the lot of its peoples, it is possible to visualize it as playing its part, as an independent scientific organization, as a valuable aid in the dual tasks of stimulating specialist research and of synthesizing the results of such research for general benefit. Possibly, in view of our expressed aims, the latter of these tasks is the more suited to our energies; but if we accept it as a major duty, we must recognize that the co-ordination of data so achieved must be made available to all interested scientists through the medium of publication.

THE SUBTERRANEAN MAMMALS OF THE WORLD

By J. R. Ellerman

(Read September 21, 1956)

Three orders of mammals have completely subterranean representatives, the rodents, the insectivores, and the marsupials. The latter contains only one subterranean mammal, which is the sole form of this kind from Australia. All of the other continents have subterranean rodents and all but South America have subterranean insectivores. A brief review is given in this paper of the different types of burrowing mammals, of the their characteristics and their distribution. The Bathyergidae and Chrysochloridae of Africa are dealt with in rather more detail than groups found in other parts of the world.

In all continents of the world are found certain small mammals which spend the greater part of their lives completely underground. Many mammals live in holes in the ground, dug by themselves or other species, and emerge by night in search of food, but the mammals now under consideration have advanced much further towards a completely subterranean existence. All of them, whether related to each other or not, share certain peculiarities of shape and build, such as short limbs, thickset and somewhat sausage-shaped bodies, and progressive reduction of the eyes, the ears and the tail until, in the most specialized species, these organs disappear altogether. As well as these peculiarities, there is usually considerable modification of the hand or the claws or, in some rodents, the incisor teeth, in order that the animal may dig efficiently.

Three orders of mammals have completely subterranean representatives, the rodents, the insectivores, and the marsupials. The latter contains only one subterranean mammal, which is the sole form of this kind known from Australia. All of the other continents have subterranean rodents, all but South America have subterranean insectivores.

As is well known, rodents are mammals adapted for gnawing. The first upper and lower incisor tooth in each side of the mouth is enlarged and rootless, the other incisors and canines are absent, and there is a wide space between the enlarged front incisor teeth and the cheek teeth. On the other hand, the insectivores often retain three upper and lower incisors and an upper and lower canine on each side, and normally there is no wide space between the canines and the cheek teeth. Moreover, when the front incisor is enlarged, it is less enlarged than in rodents, and is rooted. Insectivores are mainly insect-eaters or, in the case of the subterranean ones, feed on worms and subterranean invertebrates; rodents are principally plant-eaters, the subterranean ones living mainly on bulbs and roots.

South Africa is well supplied with both subterranean insectivores and rodents, and they are not among the most popular animals of the country because of the

damage they are liable to do to gardens. They are seldom seen alive, but traces in the shape of 'molehills' thrown up by the 'rodent moles' or 'mole-rats' are widespread all over the Union. The rodent mole-rats of the Cape belong to the family Bathyergidae. It has been customary in the past to classify the rodents in three major subdivisions typified respectively by squirrels, rats and porcupines. There are certain aberrant rodents which do not fit well into any of the three groups, and a fourth major group might well be recognized for this exclusively African family Bathyergidae. These animals combine the lower jaw typical of the porcupine group, which has the angular portion distorted outwards, with the closed infraorbital foramen of the skull which scarcely transmits any muscle and is therefore reminiscent of the squirrel group, together with the specialized hind-limb bones of the rat group, where the tibia and fibula are fused together. The Batherygidae cannot be regarded as belonging to any of the three main groups. They are the principal African subterranean rodent representatives, and they occur in almost all places south of the Sahara. In general, these animals dig with the incisor teeth which, with one exception, are very highly specialized, so that the upper pair extend backwards right over and above the upper toothrows and appear behind the toothrows in the palatal view of the skull. This structure is quite unique in the whole order Rodentia which contains perhaps a thousand valid species and is the largest order of mammals in the world as regards number of species and genera. The hand is not much specialized for digging and, as in other subterranean rodents, contains five fingers.

The most generalized genus is *Bathyergus*, a large species which is found only at Knysna, in the Cape Town district, and in the western coastal districts of the Cape Province northwards to Little Namaqualand and thence just beyond the mouth of the Orange River into Great Namaqualand. Alone among Bathyergidae, its upper incisors do not extend behind the toothrows, and the foreclaws are greatly enlarged, so that this genus digs with its foreclaws, and not with its incisors. The tail is moderately well developed and in bodily size *Bathyergus* is largest in the family, with a head and body length of roughly 12 or 13 inches at maximum. These animals live mainly in the coastal sand dunes, but are also found inland as far as the Kamiesberg in Little Namaqualand, Franschhoek and Malmesbury. All other members of the family have the upper incisors extending over and behind the toothrows, and the foreclaws are not specially enlarged. The commonest member of the family in the neighbourhood of Cape Town seems to be *Georychus*, the blesmol, which like *Bathyergus* is confined to the southernmost part of Africa; the northern limit is Belfast in the eastern Transvaal, and it is found in most of the coastal parts of the Cape Province, from at least Bathurst and Port Elizabeth westwards to Cape Town, and thence northwards to the Cedarberg, and inland to Nieuwoudtville. It is characterized by an attractive colour pattern of blackish and whitish on the cheeks, eyes and ears, by the fact that the cheek teeth are somewhat less simple in pattern than in allied genera, and by having four upper and lower cheek teeth each side. The related genus *Cryptomys*, which differs in having simpler cheek teeth and in lacking the colour pattern on the head, has a much wider distribution, being found in nearly all parts of Africa south of the Sahara, from the southern Sudan and Nigeria southwards to

the coastal districts of Cape Province. It is recorded from Bellville but evidently is not very common in the neighbourhood of Cape Town. All these South African mole-rats are said to feed on bulbs and roots, and they burrow tunnels below the ground, throwing up mounds to clear the tunnels, which mounds may be seen in almost any part of the Union.

Another genus, *Heliophobius*, is found in eastern Africa (Kenya, Tanganyika, southern Congo, Nyasaland, Northern Rhodesia, and parts of Portuguese East Africa) and is remarkable for having more cheek teeth (six upper and six lower each side) than any other living rodent. These six upper and lower teeth are not normally all in place together, as the front ones are shed before the hinder ones are cut. The last Bathyergid genus, *Heterocephalus*, is a curious and remarkable little animal from Abyssinia, Somaliland and Kenya. Its body fur is reduced to a few scattered hairs, and the animal is thus almost naked. Adult *Heterocephalus* looks very like a newly born specimen of *Cryptomys* which I examined in the Transvaal Museum, and another curious similarity was that *Heterocephalus* has only three upper and lower molars each side, or sometimes only two, which would also be the case in the young specimens of *Cryptomys* as the hinder molars would not yet be cut. *Heterocephalus* when adult is not much larger than a house-mouse. Probably, burrowing as it does in hot desert sands, it has no need of fur on its body, and its characters almost suggest that it is a *Cryptomys*-like form that in some way does not develop but remains in a permanently sub-adult state. Certainly its lack of fur is unique among rodents. The whole family Bathyergidae seems thoroughly aberrant compared with other rodents. Africa has produced many mammal curiosities, and the Bathyergidae take a high rank among these.

The other well-known subterranean mammals of the Union are the golden moles, which belong to the family Chrysochloridae of the order Insectivora. The Insectivora is not such a well-defined and compact order as the Rodentia, and the golden moles differ in some particulars from other Insectivora. The late Dr. R. Broom (1915) proposed that they should be referred to a separate order of their own, but this classification has not received much support from zoologists other than those in South Africa. More study on other Insectivora is required to ensure that the differences noted by Dr. Broom between the Chrysochloridae and the other insectivores are constant before his proposed classification can be given universal recognition. The golden moles are more specialized externally for a subterranean existence than the rodent mole-rats of Africa, but less so dentally. Thus the eyes and ears and tail are absent in the golden moles, and the digging is done with two or at most three immense foreclaws, the other fingers being rudimentary. The front teeth (incisors and canines) are all small, weak and like each other in size and form. The Chrysochloridae are an exclusively African family, and are only known from south of the Sahara, but are much more common in the south.

Authorities are not yet agreed on how many genera should be recognized in this family; there is no doubt that the giant golden moles (genus *Chrysospalax*) of the eastern Union represent a distinct genus, but the smaller ones are closely allied and might indeed, by taking a broad view, be placed within the genus *Chrysochloris*, which

was the first to be named and which contains the common species of the Cape Town district. According to Austin Roberts (1951) these animals' burrows are normally made just below the surface so that a ridge marks their course, but at times they burrow downwards and throw up mounds. These animals probably feed principally on worms, but one or two of the species found in the sandy coastal districts of Little Namaqualand and at Lambert's Bay are said to feed on small legless lizards. The typical *Chrysochloris*, which is characterized by having two main fingers with large digging claws, and by the fact that the auditory bullae appear in the superior aspect of the skull when seen from above, is found in the Cape Town district, Robben Island (one of its races is the only wild mammal named from Robben Island), the western Cape Province coastal districts northwards to Little Namaqualand, and inland as far as the plateau east of Calvinia; there is another related species in East Africa.

Two small genera, *Eremitalpa* and *Cryptochloris*, are confined to Little Namaqualand and Lambert's Bay; both are said to feed on small legless lizards, and seem to differ from the other golden moles in having three (instead of two) functional fingers. They differ from each other in the formation of the auditory bullae. *Eremitalpa* is a curious little creature which appears, at least in museum specimens, to be almost as wide as it is long. If one takes a broad view, most of the other small species, which differ from *Chrysochloris* in having the auditory bullae not visible when the skull is seen from above, could be referred to one genus for which the prior name is *Amblysomus*. Golden moles of this type are found in almost all parts of the Union except the western Cape Province coastal belt (which is the home of true *Chrysochloris*). The western limit of *Amblysomus* seems to be approximately Franschhoek and Stellenbosch; representatives are found along the southern and eastern coastal parts of the Cape Province, Natal, the eastern Transvaal, the Orange Free State, Basutoland, and inland also at Sutherland, New Bethesda, Herschel and Beaufort West. North of the Union the group extends to Portuguese East Africa, the Congo, the Cameroons and elsewhere. The giant golden moles of the genus *Chrysospalax*, which may grow to 9½ inches in length of head and body, differ very sharply in certain skull characters from their smaller relatives, and also apparently in habits. According to Austin Roberts (1951) they sometimes leave their holes and come above ground on the forest floor in search of worms. They are found at Port St. Johns, Pirie, in Griqualand East, and in parts of Natal, as well as at Pretoria, near Johannesburg, and near Wakkerstroom in the Transvaal. The family Chrysochloridae is the sole family of subterranean Insectivora in Africa, and takes the place of the true moles of Eurasia and North America, although not closely related to them.

There is only one other subterranean mammal in Africa south of the Sahara, *Tachyoryctes*, the root-rat, of East Africa (Abyssinia, Somaliland, Kenya, Uganda, and the eastern Congo). This is a rodent and its essential cranial and other characters show it to be a member of the rat group. As in all but one of the world's subterranean rodents the eyes, although small, are retained. The tail is only moderately reduced. The fur is thick and soft, and the claws are not greatly enlarged. Its incisors are well developed and presumably it digs with these, and its skull is considerably modified for fossorial life. Compared with the South African rodent-moles (family Bathy-

ergidae) it is at once separable by its normal lower jaw structure and by the fact that, as is normal in the rat group of rodents, the infraorbital foramen of the skull is open for transmission of muscle. Its cheek teeth are different in pattern from most of the other rodents of the rat group. Apparently in Kenya these animals occur up to an altitude of 11,000 feet. Judging by specimens in captivity these are thoroughly subterranean creatures and probably spend all their time below ground. When exposed to light the captive specimens seemed miserable, and were never observed to come out of the earth shelters with which they were provided. Periodically it was found necessary to clean their front teeth with a brush, and as far as I can remember they did not strongly object to the proceedings.

In Europe and Asia there are many subterranean mammals; the rodents belong to the rat group, and the insectivores are represented by the true moles. As the latter family extends also into North America, it will be more convenient to deal with the rodents first. *Spalax*, the Mediterranean mole-rat, which is found in the Balkan States, Greece, southern Russia, Asia Minor, Israel and just into North Africa in Egypt and Libya, is noteworthy as being the only rodent in which the eyes are entirely suppressed. Its skull is considerably specialized, but the upper incisor teeth are less thrown forward than is sometimes the case in these fossorial rodents, and its normal lower jaw and open infraorbital foramen, which transmits muscle, shows that it is a member of the rat group of rodents. There is no tail, and the ear is vestigial. The claws are not specially enlarged. It rarely grows to as much as 9 inches in head and body length. It feeds on roots. It seems probable that *Spalax* has no very near relatives within living rodents, and it is customary to place it in a special family Spalacidae.

The dominant group of the rat family (Muridae) in Europe, northern Asia and North America is the one which contains the voles (short-tailed field-mice) and lemmings. These differ from ordinary rats and mice in their specialized skull structure, in which the jaw muscles are more powerful than is normal, and are somewhat shifted forwards in general position, and by their complexly prismatic cheek teeth, which are often rootless (though not in the case of the two subterranean genera). Two members of this group have taken to a subterranean existence. Of these *Prometheomys*, which is only found in the Caucasus mountains, southern Russia, is a generalized species, very little changed from normal voles except that its foreclaws are extremely enlarged. But the other genus, *Ellobius*, the species of which are known as mole-voles, digs with its incisor teeth, and its skull has become transformed from the normal type in a very marked manner. Thus the incisors are very large and are abnormally thrown forwards so that, as is sometimes the case in some other subterranean rodents, it becomes impossible to measure certain cranial lengths in an accurate manner. The supraorbital ridges in at least the larger of the two species fuse further back on the skull than is normal in voles, the nasals are shortened, the palatal foramina are very small and reduced, the palate is raised up, the infraorbital foramen is peculiar in shape, and the whole effect compared with the other voles is changed almost beyond recognition. This genus is found from southern Russia across Russian and Chinese Turkestan to Mongolia, and in Asia Minor, Iran, Afghanistan and Baluchistan. The species are small animals, less than six inches long and therefore

smaller than in nearly all other subterranean rodents. The tail is usually shorter than the hindfoot, and the claws are not much enlarged.

To the east, in southern Siberia (from the region of the Altai mountains eastwards to Ussuri), northern China and Manchuria, there is yet another strange rat-like or rat-group rodent which has taken to a subterranean mode of existence. This is the genus *Myospalax*, popularly known as 'zokors'. These animals must be fairly closely related to the voles. The complexly prismatic cheek teeth characteristic of the group are rootless in the present genus, while the hinder part of the skull in some ways resembles the vole group. Although this region of the skull is reminiscent of the Mediterranean mole-rat, *Spalax*, it is doubtful if the two genera are closely allied. The infraorbital foramen in *Myospalax* is larger than in the voles. *Myospalax* digs with its foreclaws, which are relatively enormous. The tail is of medium length; the incisor teeth are not very much thrown forwards. G. Allen (1940), in his work on the mammals of China and Mongolia, states that these animals make very long burrows, that they dig with remarkable speed and that if caught and released they are very sensitive to light. They run about seeking a place suitable for digging, and a captive specimen which was kept in a bedroom one day bored its way through the entire thickness of bedclothes, mattress, blankets, quilt and all.

Before dealing with the Eurasian insectivores, one might mention that there seem to be no subterranean mammals in the large islands of the Malay Region (Sumatra, Java, Borneo, Celebes, the Philippines and, to the east, New Guinea) and that one Asiatic shrew perhaps could be added to the list of subterranean mammals. The family Soricidae, which contains the shrews, is the dominant family of the order Insectivora in the world to-day, and is common in all parts of the world (except Australasia and the greater part of South America). It is related to the northern mole family, but differs in lacking the zygomatic arch in the skull, by having the first lower incisor thrown forwards and much enlarged, and in other particulars, and the family contains the smallest living mammals. In Asia one genus, *Anourosorex*, from southern China, Assam, Burma, Indo-China and Formosa, has all the appearance of a subterranean mammal. Its tail is scarcely apparent externally, which is a most unusual character in a shrew, and its ears are much reduced. Unfortunately little seems to have been recorded about its habits. A few other shrews in the Old World have large claws, but as their habits are not well known, and their external form is not very changed, they are omitted from this work.

The dominant family of Insectivora which live below ground in Europe, Asia and North America is the family Talpidae, which contains the true moles. In this family there are one or two genera which do not burrow, such as the European desmans, which are adapted for swimming, but the majority are modified for underground life, sometimes very highly so. In Europe the commonest and best-known subterranean mammal is the common mole, genus *Talpa*, which is very highly modified for digging, and in a different way from the African golden moles. The digging is done with the whole hand, which is immensely widened, and has five very thick fingers with strong, broad claws. Further there is an extra supporting bone or bony outgrowth on the inner side of the hand, which gives extra strength. The eyes

are minute and may or may not be covered with skin. The tail is short, but present. The typical moles of Europe and Asia, may all be referred to one genus, *Talpa*, which is found in all parts of Europe (with the apparent exception of Norway). They are the only British subterranean mammals and, like several British mammals, they are absent from Ireland. In Asia, they are known from the greater part of the Siberian forest zone, Japan, nearly all parts of China, Indo-China, the Malay States, Burma, Assam, Nepal and Asia Minor. The remarkable feature of the dentition in *Talpa* is that the upper canine is the dominant front tooth, shaped like a canine, and much larger than the three small upper incisors in front of it. This structure seems unique in the family. Like many or most subterranean mammals, the European mole throws up mounds during its peregrinations, and on that account is not very popular with gardeners. These moles are ravenous and somewhat pugnacious little animals, and chiefly feed on earthworms but also on snails, insects, etc. They do not live well in captivity. According to Bobrinskii (1944), in the U.S.S.R. the gestation period is 40 days, mating takes place in the early spring, and at the end of April and in May 3–7 (maximum 9) young are born, which are naked and helpless.

There are three other genera of the family Talpidae in Asia which may be assumed to lead a subterranean existence, as they are at least partly modified for digging. All of these are related to the North American moles, and all of them differ from the genus *Talpa* in having small canines. *Scapanulus*, from the Chinese States of Szechuan, Kansu and Shensi, has the front upper incisor enlarged, and longer than the other front teeth. It has a short, hairy, almost bushy tail, and a broad hand, less broad than in the typical moles, but apparently highly specialized for digging. *Urotrichus* from Japan resembles it, but differs in having a weaker and narrower hand and is therefore perhaps less of a burrower. Its tail is well developed, and in a few specimens it may be half the length of the head and body; it is hairy, almost bushy. Its front upper incisor is enlarged. *Scaptonyx*, from the Chinese states of Szechuan and Yunnan, and from northern Burma, differs from the last two genera in having the front upper incisor not particularly enlarged, so that there is no very dominant front tooth. Its tail is similarly hairy, and apparently its hand is not greatly broadened; perhaps it is most like that of *Urotrichus*, but I have been able to examine only a very few specimens.

All of the North American moles are apparently burrowers. Much the least specialized is *Neurotrichus*, from the western United States (California northwards) into British Columbia, Canada. Compared with most other members of the family this genus has the hand not very much broadened, and its front upper incisor tooth is not at all enlarged in the specimens I examined, so that there is no very dominant front tooth. Moreover its tail, which is well developed, is not very hairy, which character separates it from the Asiatic *Scaptonyx*. According to Anthony (1928) it seems to spend some time on the surface of the ground, and prefers a damp, swampy habitat. Perhaps it is less subterranean than the other North American moles, and it is smaller in size than the other American species. The other North American moles have the hand immensely widened, and in appearance much like that of the European mole, as described above. Much the most specialized is *Condylura*, the star-nosed

mole, from several places in south-eastern Canada and the north-eastern United States, which has a peculiarly developed snout terminating in a fringe of 'twenty-two fleshy processes forming a wide, naked nasal disk'. These processes are symmetrically arranged on either side of a median line, and they give the animal its English name. So far as I know, the use of this curious specialization of the snout does not seem to be known. The animal has a very long tail for a mole. From the few specimens I have been able to examine, the dentition is quite different from the other moles. These specimens had the front upper incisor enlarged and pointed forwards, and the main tooth immediately behind longer, large, and shaped like a canine, so that it appears this animal combines the best of two worlds as far as dentition is concerned, by a combination of a canine-like tooth plus an enlarged front incisor.

The genus *Parascalops* is found in the eastern United States, and in south-eastern Canada. It differs from the commoner North American genera in having the tail much more hairy, and is very reminiscent of the Asiatic genus *Scapanulus*, but the specimens I examined of *Parascalops* had the front upper incisor tooth scarcely enlarged, and it has 44 teeth whereas *Scapanulus* has only 36 teeth in all. Dental formulae are known to be individually variable in some members both of the northern mole family and in the African golden mole family, but not to the extent of the number of teeth which separate *Scapanulus* from *Parascalops*. The other two genera of North American moles both have the front upper incisor clearly enlarged (and the canine not so), but otherwise they look much like European moles in general appearance, with a much broadened, five-fingered hand, and a short and rather naked tail. The most widely distributed genus is *Scalopus*, which ranges over much of the United States, southwards into Mexico, and northwards into Ontario, Canada. It normally has 36 teeth, and its hand is broader than long. The genus *Scapanus* is not unlike it, but has 44 teeth in all, and its hand is about as broad as long, therefore not quite so widened as *Scalopus*. *Scapanus* is western in distribution, from California northwards into British Columbia. Some interesting accounts of its habits were given by Anthony (1928). He states that these moles are active creatures, and in favourable soil make an extensive series of runways. It is said to have a central nest-chamber or retreat and from this base it pushes out for considerable distances. The runway is stated frequently to pass so close to the surface of the earth that the roof of the tunnel is raised above the ground-level. When this is not the case the mole must get rid of loose earth in another fashion, and the loosened earth from deep tunnels is pushed up in a short, vertical chimney and piles up on the surface as a mound. Anthony states that these moles are surprisingly strong, and literally swim through the soil. He states that he has watched the species at work just below the surface of a meadow, and that the soil heaved and lifted and the sound of cracking grass-roots was clearly audible for several feet. He also states that from observations on moles in captivity, it has been noted that the snout plays an important part, being thrust ahead to make the preliminary opening, when one forefoot follows and sweeps outward to enlarge the tunnel; and that the tail is a sensitive tactile organ and serves to guide the animal when it moves backwards along a runway. The fact that the fur strokes as easily one way as the other would also favour progress in either direction, and this is often the case in other subterranean mammals.

In addition to all these moles, North America possesses a large group of subterranean rodents, which are very different from those which have already been noted as occurring in Europe, Asia and Africa. These belong to the exclusively American family Geomyidae. They are known as 'pocket-gophers', and have much of the typical jaw-musculature of the squirrel group. The lower jaw is normal (at least when compared with porcupines or the African rodent-moles); there is a small infraorbital foramen which does not transmit muscle, and the zygomatic plate is tilted strongly upwards so that the masseter muscle rises up it to the superior border of the snout. On the other hand these animals differ from squirrels and resemble rats and their allies in having the tibia and fibula of the hindleg fused, and in having the jugal bone in the skull shortened. The family is further peculiar in possessing large cheek-pouches, which open externally. Many rodents have cheekpouches but all of them except one closely related North American family have them opening internally. The cheek teeth in the Geomyidae are rootless and simple. The two principal genera (American authors recognize more) are *Geomys* and *Thomomys*. The latter lacks the grooves on the front surface of the upper incisors of the former and their collective distribution is from Canada to Panama. The foreclaws are very large, and it appears that a great deal of the digging is done with these. It is said that the animals fill their cheekpouches by pushing food into them with their forepaws, and that when the pocket-gopher wants to empty his pouches he brings his forefeet back along the sides of the head until they are behind the pouches, and then presses them firmly against the head and pushes them rapidly forwards; in this way the contents of the pouches are promptly dumped in front of the animal. It is further said that the tail is supplied at its tip with tactile nerves and is used as a guide when the animal runs backwards, which they do as easily as they run forwards. They feed principally on roots and bulbs, and have a liking for potatoes and garden vegetables. They are reported to be active animals, to burrow long distances, and to do considerable damage.

In South America, where insectivores are practically absent, there are a few subterranean rodents, two of the most specialized of which belong to the porcupine group. These have the lower jaw with the angular portion distorted outwards (as in the African family Bathyergidae) but differ in having the infraorbital foramen of the skull widely open for muscle transmission, and in having the fibula not fused with the tibia in the hindleg. Both of these characters are normal for the porcupine group of rodents. The 'tucutucu', genus *Ctenomys*, has a wide distribution, from Patagonia northwards to southern Brazil in the east and Peru in the west. They have the usual appearance of subterranean rodents, with reduced eyes, ears and tail, enlarged foreclaws, and thickened incisor teeth. The cheek teeth are rootless and simple and the hinder upper molars are very small. Another subterranean rodent which belongs to the porcupine group, genus *Spalacopus*, lives in Chile. It is rather small and its claws not greatly enlarged; it appears that its incisor teeth are its chief instruments for digging. The hinder parts of the upper ones curve round and on each side form a projection nearly overlapping the second upper cheek tooth on the outer side of the toothrow, a structure without parallel in Rodentia. One or two of the rats of South America, notably the genus *Notiomys* from Patagonia, seem to be subterranean but are not excessively specialized apart from their enlarged foreclaws.

In the Island of Madagascar, there is a family of insectivores, called the Tenrecidae which agree with the African golden moles in having V-shaped main upper cheek teeth whereas these teeth are W-shaped in most other Insectivora. However they differ in having the zygomatic arch of the skull absent or imperfect, in being much less specialized or not specialized for underground life, and in various other details. One of the genera, *Oryzorictes*, is said to be fossorial, and to burrow in the ricefields. This animal has the appearance of other moderately specialized subterranean mammals, though it is nothing like so extremely modified as the Eurasian moles or the golden moles. It has a large upper canine, and it has five fingers which are quite well developed and which bear claws. The related genus *Nesoryctes*, also from Madagascar, has less than five fingers. In the few specimens I have been able to examine, which were not in very good condition, it appeared that there were three functional fingers, and probably traces of one of the outer fingers are retained as well.

The only other subterranean mammal to be noted is a marsupial, *Notoryctes*, the 'marsupial mole', which was described from Central Australia in 1891. This little animal is very highly specialized indeed for subterranean life, and bears a most striking resemblance to the South African golden moles, *Chrysochloris* and allies. It has a visible tail (about a fifth of the length of the head and body in the specimen I have been able to examine), but otherwise is very like *Chrysochloris*. Its hand, which has two enormously enlarged foreclaws and the other fingers absent or much smaller, seems almost identical. The teeth, also, are very similar to those of *Chrysochloris*. Differences include the reported presence of a pouch in which, as in most marsupials, it probably carries its young, and, in the skull, the narrower nasals, weaker snout, rather wider frontal bones and other details. The resemblance is, of course, a remarkable case of parallel evolution; the animals belong to different orders and are not related. Mention of *Notoryctes* brings us to the end of our survey of the world's subterranean mammals.

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THE PHYSIOGRAPHY AND SURFACE GEOLOGY OF THE HOPEFIELD FOSSIL SITE

By J. A. Mabbutt

Department of Geography, University of Cape Town

(Read September 21, 1955)

The Hopefield site lies 300 ft. above sea-level, on the margin of the 'Sandveld Plateau' and ten miles inland from Saldanha Bay. It marks the inner margin of limestone ridges (Dorcasia Formation), product of a littoral dune invasion lasting from the Kamasian into the Gamblian, where these give place to the silvery-grey quartz sands of the Sandveld. The characteristic fossil horizon is a nodular calcrete which apparently represents the drying pan floors in which the fossils accumulated. It is traversed by sinuous ferricrete ridges that are interpreted as ferruginized dune cores marking a preceding moister period; similar ferricretes are of regional extent and postdate the Minor Emergence at the coast. The fossil layer is capped by surface limestones and ferruginized sands, the latter representing a second moister period.

The fossils at this horizon date from a single period, to which Saldanha Man must be assigned; they reflect a bush-steppe fauna of late Kanjeran affinity and are associated with artefacts representing the final phase of the hand-axe culture. After the cementation of the fossils, shortly before and during their burial, the site underwent a phase of Stillbay (Middle Stone Age) occupation.

The geological context generally supports the early Gamblian or late Kanjeran dating of the site from palaeontological and archaeological evidence.

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I. Physical Setting

The Hopefield fossil site occurs on the farm Elandsfontein (lat. 33° 05′ S., long. 18° 15′ E.) in the Hopefield District of the Cape Province and lies 300 ft. (90 m.) above sea-level, 10 miles (16 km.) inland in a north-easterly direction from the head of Langebaan Lagoon, the innermost reach of the Saldanha estuary (fig. 1). It is 60 miles (97 km.) in a straight line NNW. from Cape Town. The farm is situated in fairly flat sandy country broken only by low dune ridges and shallow drainage hollows and with a thick cover of evergreen shrubs. The climate is semi-arid, the mean annual rainfall decreasing seawards from 12·72 in. (31·3 cm.) at Hopefield to 10·35 (26·3 cm.) at Langebaan, and is typically Mediterranean, with rain coming mainly between May and September inclusive. Summers are dry and warm, although tempered slightly owing to the proximity of the Atlantic Ocean;

the mean maximum temperature for February at Darling is 83·4° F. (28·6° C.). This season is characterized by strong southerly winds.

The broader physical setting is shown in figure 1. The Atlantic coast south of the Great Berg River is bordered by a coastal plain near the 300 ft. (90 m.) level; it is particularly impressive about the lower Great Berg River, whence it extends far inland in the Piketberg Karroo. Its perfection and constancy of altitude, the

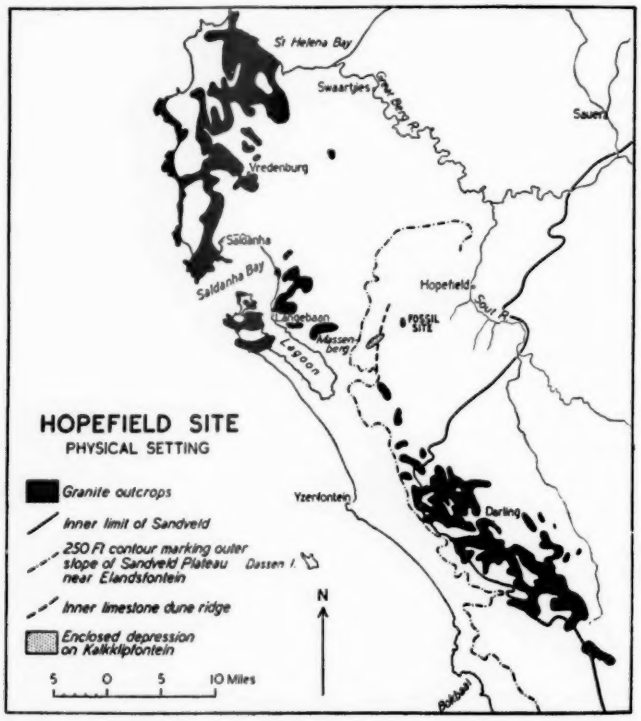

FIG. 1

The physical setting of the Hopefield Fossil Site.

immaturity of the valleys across it and its sharp termination against the bases of residual hills stamp it as a marine terrace. Its surface is partly erosional and partly depositional; it has been cut in unresistant shales and slates of the Malmesbury Series, but its outer edge is masked by older sands which underlie the surface dunes. From its regional context we may term it the 'Sandveld Plateau'. There is no direct evidence of its age, but it forms part of a coastal plain extending from Natal round to South West Africa and antedating the latest phase of rejuvenation seen

in the South African physical landscape, for it is gashed by post-Kageran* river cycles. The glacio-eustatic beaches of Kamasian and later date are staged below its outer edge. We may therefore tentatively suggest a Kageran date as an upper age limit, but the terrace must represent a long period of stable base-level extending back into the Upper Tertiary.

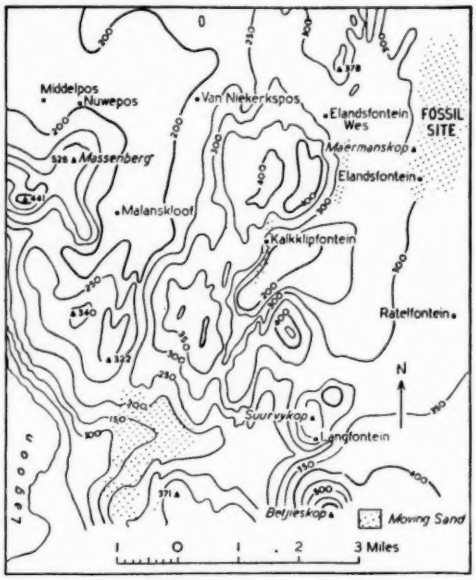

FIG. 2
Detailed contour map of the area of the site.

The outer margin of the Sandveld Plateau and the beginning of the seaward slope beyond are indicated in figure 1 by the 250 ft. (75 m.) contour. East and north-east of Elandsfontein the Great Berg River and its tributary, the Sout River, are sharply incised to a depth of 100 ft. (30 m.) below the plateau surface, and the descent to their valleys is abrupt, but the slopes leading westwards to Saldanha Bay and Saint Helena Bay are gentler and more complex. The following physical elements can be distinguished:

(*a*) Discontinuous terraces, probably of marine origin, below the Sandveld Plateau level, namely —
  (i) a fragmentary terrace at 150–200 ft. (45–60 m.) north of the Massenberg, and
  (ii) broad coastal flats at approximately 50 ft. (15 m.) above sea-level and extending inland east from Saldanha Bay.

* The subdivisions of the Pleistocene employed here are in accord with the resolutions of the Third Pan-African Congress on Prehistory, Livingstone, 1955, to the effect that the terms Lower, Middle and Upper Pleistocene be avoided in Africa excluding the Mediterranean littoral, and that Kageran, Kamasian, Kanjeran and Gamblian be used wherever two of the lines of evidence, palaeontology, archaeology and geology, are available. These terms so used bear no climatic connotation outside East Africa.

(*b*) Residual highlands formed by the Cape Granite intrusive into the Malmesbury Series, once islands and now rising sharply from the Sandveld Plateau and the lower terraces. They fall into three groups:

(i) the Vredenburg plateaux in the north;

(ii) the group of hills behind Langebaan;

(iii) in the south, the coastal hills of the Darling area, trending NW.–SE. with the structural grain of the country and parallel with the coast, closely hemming in the southern extension of the Sandveld Plateau. These hills terminate north-westwards in Betjieskop (fig. 2), approximately 5 miles (8 km.) south of the fossil site.

(*c*) Broad valleys leading down from the Sandveld Plateau to the lower terraces. Two lines are of primary importance, namely those occupying the gaps north and south of the Langebaan granite hills and directed towards Saldanha Bay and Langebaan Lagoon respectively.

(*d*) The limestone dune ridges which occupy the littoral strip between Yzerfontein and Langebaan, a series of calcreted dunes trending N.–S. discussed in some detail with the geology of the area. These old dunes have advanced inland, breasting the slopes and barring the valleys leading down from the Sandveld Plateau; their advance has been facilitated by the open ground south of the Langebaan hills and here the dune ridges lie farthest inland. One dune actually traverses the fossil site, a second, more prominent and marked in figures 1 and 2, borders it closely on the west, running northwards from Betjieskop, possibly overlying a prolongation of the granite ridge, and attaining an altitude of 400 ft. (122 m.). It will be seen from figure 2 how this and neighbouring ridges have barred the main drainage line, which leads south-westwards from the fossil area towards the valley running westwards to the head of Langebaan Lagoon. In this way has been enclosed the depression below 200 ft. (60 m.) on Kalkklipfontein, cut off by a 200 ft. (60 m.) barrier from its former outlet. This obstruction of regional drainage is considered to have played a vital role in the past history of the fossil site.

II. Description of the Site

The position of the site is first indicated to the approaching visitor by cream-coloured, mobile sand-dunes which cover an area of approximately 2 square miles (5·2 ha.) north of the farmhouses. The moving dunes are quite localized amid the scrub; they probably originated from burning or overgrazing and have existed for half a century at least, for they are marked on a geological map of the area made in 1906. While the exposed fossil horizon lies between 10 and 20 ft. (3 and 6 m.) below the general level of the sandy plateau surface, the dune crests rise 20–50 ft. (6–15 m.) above it; the hollows and ridges are clearly complementary, the dunes consisting of sand stripped off by the wind in baring the fossil floors.

For descriptive purposes the site may be divided into the three areas mapped separately in figures 3–5.

(*a*) Main Site

This lies adjacent to and among the mobile dunes described above. It begins half a mile (0·8 km.) north of the farmhouses and comprises the largest and most fossiliferous area. It may be subdivided as follows:

(i) In the west, *Homo Bay* (fig. 3), a N.–S. depression 1,100 yds. (1 km.) long and 150 yds. (137 m.) across at its widest point, the floor lying at 290 ft. (88 m.) above sea-level. The depression is almost separated into northern and southern halves by blown sand. The southern portion is floored by the grey-white or light-brown nodules and sands with which the fossils occur; in the north, this floor is partly capped by tabular masses of white sandy limestone and by light-brown

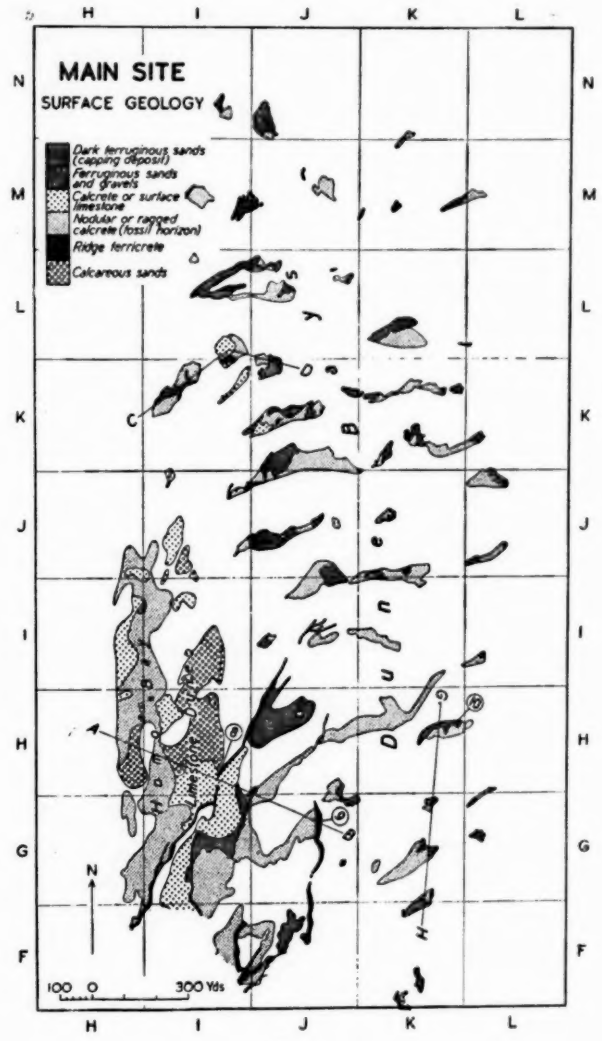

FIG. 3

Surface geology of Main Site. Section lines are those of figure 14, while numbers in circles locate corresponding figured sections. Grid squares serve to refer to specific points; e.g. GH 13 indicates column G, row H, and one-tenth of the square east and three-tenths north from the south-western corner.

sandstones which rise 2–3 ft. (0·5–1 m.) above the fossil horizon. The depression is referred to as Homo Bay from the discovery, in its northern half, of fossil fragments of the skull of Saldanha Man.

(ii) *Limestone dune and ferricrete ridges.* Except at its southern end, where it is bounded by a 15 ft. (4·5 m.) northwest-facing escarpment of ferruginous sandstone or *ferricrete* (Plate II A), Homo Bay is flanked on the east by a dune ridge of calcareous sands largely capped by white sandy limestones or *calcretes*. The ridge is 100 yds. (90 m.) across and rises to 320 ft. (98 m.) above sea-level; it was probably the only fossiliferous or associated deposit originally outcropping through the sands, and is an outlier of the coastal limestone ridges referred to above. The ferricrete escarpment is apparently overlapped by the south-eastern corner of this limestone dune, but it continues beyond, north-eastwards, for a further 550 yds. (500 m.). A similar ferricrete ridge runs parallel to it, 400 yds. (365 m.) to the east.

(iii) *Dune Bays.* The northern and eastern parts of Main Site consist of long, narrow corridors between parallel dunes. In the north, the dunes trend E.–W., transverse to the prevalent southerly winds; they have prominent slip faces on their northern sides and often show the crescentic horns of true barkhans. Farther south, they change to a NE.–SW. direction, thus linking with the N.–S. trend which is apparent in that part of Main Site already described and which is also typical of the ferricrete ridges where they continue south of the site towards the farmhouses.

The inter-dune corridors are approximately half a mile (800 m.) long, and each is broken by sand ridges into two, three or four aligned basins or *bays*, the spacing and alignment becoming less regular towards the northern limit of the site. In the bays the fossils occur on a definite horizon, associated either with a layer of whitish brown calcareous sand nodules or a floor of ragged white calcrete. To the south and east this fossil horizon is extensively capped by a flat layer of dark ferruginous sands from 2 to 8 ft. (0·5 to 2 m.) thick (Plate IV A), across which the dunes originally moved, but which is easily undercut by wind and sand blast and stripped to the nodular fossiliferous horizon. The fossils are slowly etched out from their containing deposit as sand is swept across the bay floors by southerly winds, particularly during the summer months; during the winter, more frequent northerly winds and occasional rains cause sanding up of the bays and a slowing or reversal of this process.

(*b*) Farmhouse Site

A second group of fossil exposures occurs in the neighbourhood of the farmhouses and comprises three separate areas which from their relative positions may be termed Farmhouse West, North and South (fig. 4).

(i) *Farmhouse West.* This area apparently owes its exposure to trampling by stock, for on the north-eastern side the boundaries are those of the camps affected. The site lies between what appear to be continuations of the two ferricrete ridges described on Main Site; the ridges here diverge somewhat, that to the north-west is mainly obscured by sand, but the eastern ridge is more prominent and forms the boundary of the site in that direction. At the foot of this ridge is the *fontein* from which

the farm is named; it fixes the level of ground water hereabouts at 280 ft. (85 m.) above sea-level.

The fossiliferous horizon is a nodular calcrete, rather more massive than on Main Site and occurring as a low platform at 285 ft. (87 m.). It is less rich in fossils or artefacts than on Main Site. Locally, the wind has scoured hollows 5 ft. (1·5 m.) or more deep into the sterile calcareous sands below. At the south-western corner of the site the calcretes are capped by dark grey sands and white limestones (fig. 13) which may formerly have been more extensive across the area; these are in turn overlain by compact dark grey sands which form a layer beneath the adjacent dunes.

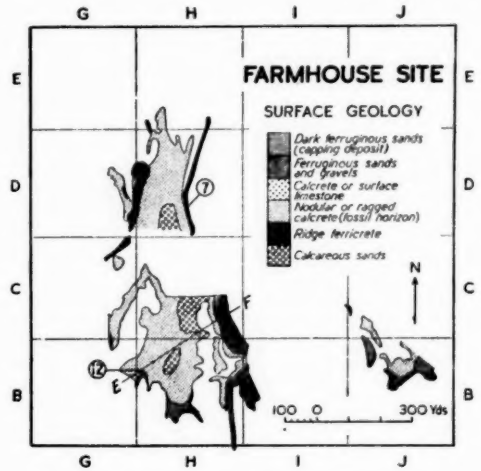

FIG. 4

Surface geology of Farmhouse Site. Section line is that of figure 14, while numbers in circles locate corresponding figured sections.

(ii) *Farmhouse North.* To the north of Farmhouse West is a second, smaller fossiliferous area in which the process of stripping is less advanced. The ferricrete ridges here converge and lie only 125 yds. (115 m.) apart, forming the lateral boundaries of the site. They rise less than 10 ft. (3 m.) above the intervening fossiliferous floor, which lies at 285 ft .(87 m.) and which consists of sands and calcareous nodules similar to those on Main Site. A spread of khaki-grey ferruginous gravel appears to cap the fossil horizon at one point, while at the northern end of the site, where it fingers out in dune embayments, a tiny outcrop of white cellular limestone was also proved to overlie the nodular zone.

(iii) *Farmhouse South.* This, the smallest of the three sub-areas, lies wholly east of the ferricrete ridges and is geologically similar to the eastern and south-eastern parts of Main Site. It is framed on three sides by a narrow platform of the dark ferruginous sands which cap the fossil zone, the sands here being 9 ft. (3 m.) thick and the upper surface of the capping standing 310 ft. (95 m.) above sea-level. The central depression is floored by the usual grey-white or light brown nodules, but the fossil zone and underlying sands have here undergone more than the normal subse-

quent ferruginization. This area is very poor in fossils and such fragments as do occur are deeply iron-stained and badly preserved.

(*c*) West Site

This consists of four wind-scoured hollows aligned N.–S. at the foot of the limestone ridge which rises sharply to about 400 ft. (125 m.) above sea-level one and a half miles (2·4 km.) west of Farmhouse Site (fig. 5). The sandy plateau descends

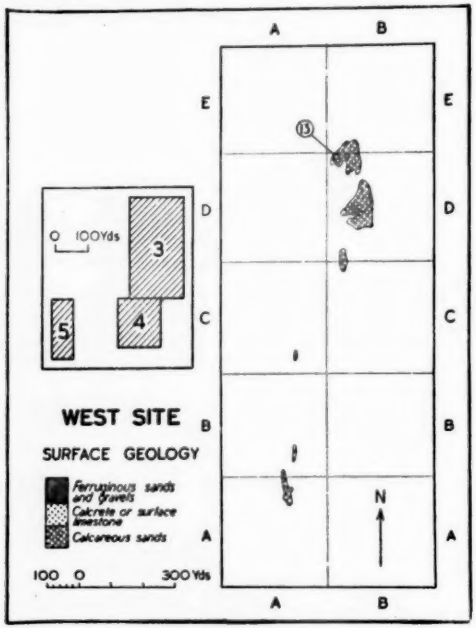

Fig. 5

Surface geology of West Site. Number in circle locates corresponding figured section. Inset map shows relative positions and areas of figures 3, 4 and 5.

to 260 ft. (80 m.) at the base of the ridge, whence the fall is southwards towards the Kalkklipfontein depression (fig. 2), probably along a former drainage line. Only the northernmost depression is significant geologically or as a source of fossil material. In the north-western corner of this depression the fossiliferous horizon is seen as a ledge of white limestone 1 ft. (30 cm.) thick overlying ferruginous sands at 240 ft. (73 m.); a zone of ferruginous sands 2–3 ft. (60–90 cm.) thick also occurs at the base of the dunes immediately above the limestones (fig. 14). A ferruginous gravel outcrops at the same level at the opposite end. The depression has been scoured to a depth of 20 ft. (6 m.) into the soft, grey-white calcareous sandstones beneath the fossil floor. Fossils, artefacts, and many rounded boulders litter its lower slopes and floor. Elsewhere the level of the fossil horizon is indicated only by the red-brown ferruginized sand horizon above the lower slopes of light grey sand and by the

occurrence of fossils which have fallen to lower levels. Grass planting has aided sand encroachment on the southern and eastern margins of the hollows; only at the north-western limit of the largest hollow has wind erosion been sufficient to maintain the exposure of the old surface.

In Table I are listed the areas in acres of (*a*) the exposed site and (*b*) the fossiliferous horizon in each of the areas described separately above.

TABLE I

	(*a*)	(*b*)
Main Site		
Homo Bay	29·9	29·9
Calcareous Dune	24·3	24·3
Dune Bays	63·8	41·1
Farmhouse Site		
Farmhouse West	21·2	18·7
Farmhouse North	10·2	9·8
Farmhouse South	2·8	1·6
West Site	3·7	0·1
TOTAL	155·9	125·5

III. SURFACE DEPOSITS

1. BASAL SILVER-GREY SANDS

These occur immediately beneath the fossiliferous horizon on Main Site east of the calcareous dune and formed the basal horizon of all sections examined in this area. They are typically sterile, uncemented, silver-grey sands, locally stained darker from the ferruginous sealing deposit above the fossiliferous horizon, with a low lime content (2–4%) which increases westwards towards the calcareous dune. The sands consist of quartz grains plus only a little interstitial lime; no accessory minerals were observed.

The coarse fraction (>20 mesh)* includes grains of very high roundness (0·9)† and high sphericity (0·7–0·9) with the surface frosting characteristic of wind-borne sand (Bond, 1954), while the bulk of the remainder consists of fairly equidimensional (±0·7) but definitely subangular (0·5 and less) grains without frosting, suggesting that water may have played some part in their accumulation. This is borne out by the grading histogram, which reveals a wider sorting then that of a local aeolian sand (fig. 6*d* and 6*g*).

These sands are physically identical with those described as 'older sands of uncertain thickness' underlying the drift sands of the Melkbosch-Mamre area

* Most of the surface deposits at Elandsfontein fall into the category of coarse sand and it has proved possible to differentiate them using only 20, 40, 60 and 80 mesh sieves.

† The *sphericity* of a particle is defined as $\frac{d}{a}$; where d is the nominal diameter (the diameter of a sphere of equal volume) and a the maximum intercept through the particle. *Roundness* is given as $\frac{r_1}{r_2}$ where r_1 is the average radius of corners and edges and r_2 the radius of the maximum inscribed circle (Krumbein and Sloss, 1951).

(Haughton, 1933). It is suggested that they originated locally as a littoral deposit at a time when sea-level stood higher and the shoreline lay farther east than at present; that a minor component was introduced by wind action and that they have been largely leached of an original shell lime content. It seems reasonable to associate their origin with the marine planation and subsequent emergence of the prominent plain at or near the 300 ft. (90 m.) level about the lower Great Berg River valley, for which the writer has above postulated an end-Tertiary to Kageran age.

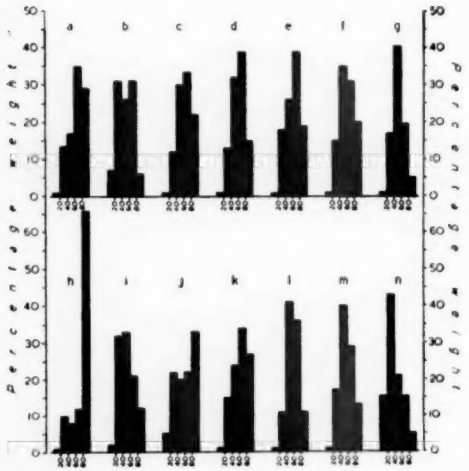

FIG. 6

Grading histograms of surface deposits on the Hopefield Site: a calcareous sands, b calcareous dune sands, c calcareous sand nodules (fossiliferous horizon), d basal silver-grey sands, e dark sand capping, f light brown sandstone overlying calcrete in Homo Bay, g 'Sandveld' sands, h surface limestone from West Site (fig. 8), m ferruginous sand at dune base, West Site (fig. 13), n mobile dune sands, Main Site.

2. CALCAREOUS SANDS

We may distinguish between two related types:

(*a*) In the wind-excavated hollows on West Site, beneath the fossil horizon on Farmhouse West and near the calcareous dune on Main Site they occur as soft grey-white calcareous sandstones, sugary in texture and generally structureless, although the wind has locally etched out signs of dune bedding, and with moderate (6–11%) lime content. They have yielded shells of species of the land gastropod *Trachycystis* at a depth of 20 ft. (6 m.). On West Site they are eroded to a depth of 20 ft. (6 m.) (i.e. to 220 ft. (67 m.) above sea-level) without the base being exposed. They can be differentiated from the silver-grey sands by their higher content of fine interstitial lime (fig. 6*a*), but the coarse fraction shows the same well-rounded, frosted quartz grains—in fact, the evidence of aeolian transport is even stronger.

(*b*) On Main Site they build the calcreted dune which runs N.–S. and borders Homo Bay on the east (fig. 3). The dune sands are whiter and harder and have a higher lime content (30% is normal in the upper layers); they also contain a small amount of calcium phosphate (*c.* 5%). They are clearly terrestrial and aeolian, as shown by

(i) dune foreset bedding along the frontal (eastern) dune face;
(ii) successive sloping encrusted surfaces, marking stages in deposition;
(iii) shells of the land snail *Trigonephrus globulus*, a species characteristic of arid sand environments;
(iv) the occurrence of fossil mammalian bones in the upper 1–3 ft. (30–90 cm.);
(v) a much higher percentage of coarse (>20 mesh) well-rounded grains (fig. 6*b*), all exhibiting frosted surfaces, suggestive of selective concentration of the coarse fraction in (*a*) above.

The calcareous sand-dune on Main Site is an outlier, in the van of the belt of limestone ridges which begins immediately beyond West Site with the ridge marked in figure 2 and which extends unbroken to the coast between Yzerfontein and Langebaan. The general trend is northerly, roughly parallel with the coast. The coastal limestones in the Saldanha Bay area have been described in detail by du Toit (1917) and named Dorcasia Limestones from their content of shells of land snails of the Dorcasianae family, to which *Trigonephrus* belongs. His description of these calcareous sands applies equally well to those on Elandsfontein; they are similar in their lime (12–15%) and phosphate content, in the trituration of any marine shells and in the occurrence within them of complete land shells and occasional

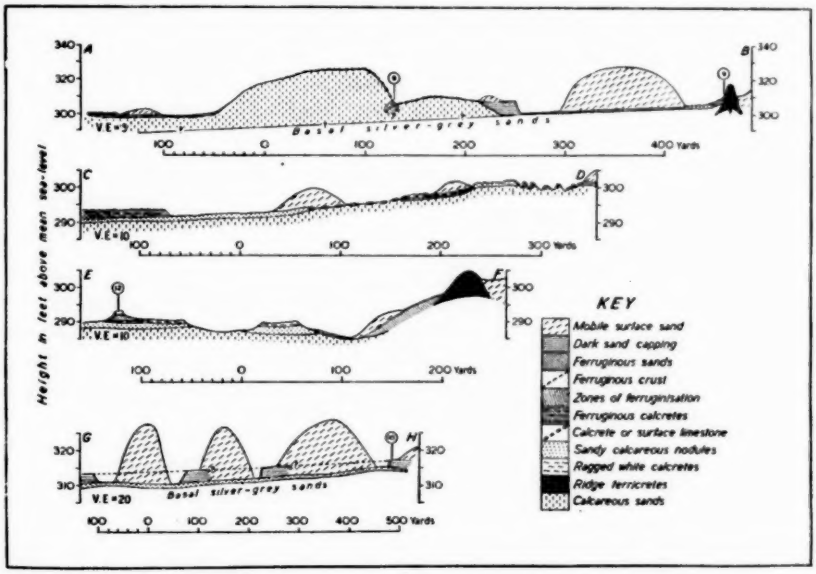

FIG. 7

Cross-sections demonstrating the apparent relationships of surface deposits on Main and Farmhouse Sites. Section letters are those of figures 3 and 4; numbers in circles locate the corresponding figured sections.

mammalian fossils. Du Toit observed that the Dorcasia Limestones overlie the phosphatized shell-beds on the 20–25 ft. (6–8 m.) raised marine terrace, and from their attitude in the cliff sections he concluded that they must formerly have extended over what is now sea. He regarded them as having 'accumulated on a beach or in close proximity to the sea under the action of the wind'. Du Toit's views have recently been substantiated by Truter who concludes that 'the entire succession exposed above present sea-level is aeolian in origin, except the deposits in the valley at Langebaan Road and to the west of the sand ridge immediately west of Langebaan Road, which are lagunal or estuarine'.* Haughton's (1932) detailed description of the latter, which lie at 105 ft. (32 m.) above sea-level, suggests that they may have formed in an inland pan not necessarily related to the prevailing sea-level, as may other phosphatic sands exposed by the Buffels River at a similar elevation near Bok Baai.

The writer has observed that similar calcareous sands overlie the 20–25 ft. (6–8 m.) raised beach in the headland at Yzerfontein (Plate I B), and there can be little doubt that at the coast the Dorcasia Limestone postdates the Minor Emergence. Furthermore, since the ridges now bar the open valleys leading down from the Sandveld Plateau to at least the 150 ft. (45 m.) contour, they must be wholly younger than that plateau. It has been remarked by Truter that 'the proportion of shell grit and the calcareous content . . . decrease eastwards, whereas the proportion of quartz grains increases inland, in which direction the beds grade into dune sand (the older dune sand which is to be found below the younger dunes now largely fixed by vegetation)'†, and this, together with the observed geographical continuity of the dune belt, might indicate a single if protracted invasion, probably beginning before but continuing during the regression from the Minor Emergence beaches to below present sea-level and possibly motivated by the consequent shallowing of the off-shore zone. As indication of an upper limit to their age at the coast we may note the recovery from them at Bloembosch, north of Yzerfontein and less than 2 miles (3·2 km.) inland, of mammalian fossils including *Equus capensis* and *Homoioceras bainii*, which occur at Elandsfontein (Cooke, 1955). Haughton (1933) reports the occurrence of fossil fragments of these same species in a terrestrial calcareous sandstone now below sea-level in Table Bay, blocks of which are cast up on the beach following storms. Whatever the age of the dune invasion, it is certainly significant that the Hopefield site marks its landward limit and the point at which the passage to the quartz sands of the Sandveld is accomplished.

3. Ridge Ferricretes

Two sub-parallel ridges of dark, red-brown, ferruginous sandstone or *ferricrete*, approximately 400 yds. (365 m.) apart and with a northerly or north-easterly trend, form striking surface features in the southern part of Main Site (Plate II A), whence they are traceable through the bush south of the site for half a mile (0·8 km.) as far as the farmhouses. The old farmhouses were built on the eastern ridge and the

* Personal communication from Dr. F. C. Truter.
† Personal communication from Dr. F. C. Truter.

fontein occurs at its foot, apparently opposite a transverse break. The ridges are best developed for approximately 400 yds. (365 m.) into Main Site; north of this point they become lower and discontinuous beneath the dunes, at the same time converging; south of it both crests descend southwards at equal rates (308 to 290 ft. (94 to 88 m.) in the west, 317 to 300 ft. (97 to 91 m.) in the east) following the regional slope of the terrain. The steeper west faces of the ridges rise between 5 and 15 ft. (1·5 and 5 m.) above the ground to the west, but the eastern slopes are generally imperceptible; hence the two ridges form steps descending westwards. In their southern, vegetated portions the ridges are broader and partly masked by iron-stained sands, but on Main Site these sands have been stripped off and form an important component of the mobile dunes; in the eroded area the ridges stand out by virtue of their hardness as a result of ferruginization, the induration increasing on exposure.

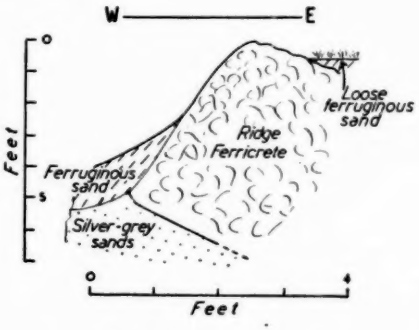

FIG. 8
Section in ferricrete ridge on Farmhouse North, HD 43 in figure 4.

Because of this hardness and massiveness the ferricrete ridges have resisted complete sectioning and geologically remain something of an enigma. Their asymmetry at first indicated that they were escarpment outcrops of easterly-dipping ferricrete layers, and this was initially supported by a test trench on Farmhouse North (fig. 8). Against this stood the invariable narrowness of the ridges and their overall straightness despite variations in altitude. Later sections (fig. 10) showed that ferruginization had occurred along narrow zones and to some depth, apparently sufficient to affect the local water table. Many of the minor features of the ridges are secondary, the results of wind erosion since their exposure. For instance their orientation is such that sand tends to be piled against their eastern or south-eastern flanks while the western faces are swept clean or undercut by sand blast due to the southerly winds. However, the ridges trend sufficiently obliquely to the prevalent wind direction and exhibit so many minor sinuosities and transverse branches that their linearity must be primary; observation suggests that the same holds for their asymmetry, for a section at the south end of Homo Bay showed the west face of the ferricrete ridge to slope down at an angle exceeding 45° for a vertical distance of 10 ft. (3 m.). Any satisfactory explanation of the ridges must consequently account for their narrowness, asymmetry, overall straightness and sinuosity in detail.

The ridge ferricretes are hard, red-brown or dark brown, ferruginous sandstones, cellular or clinkery in texture, in which closely packed quartz grains have been cemented by hydrated iron oxides. Ferruginization has proceeded inwards and downwards; the crests and outer surfaces of the ridges are often darker and more indurated, while there is evidence of decreasing compactness and ferruginization below, with pockets of loose sand encased in irregular ferruginous crusts.

There is proportionally more fine material than in the calcareous dune sands, chiefly as a cement, and a much smaller coarse fraction, although the same large, extremely well-rounded grains *are* present (fig. 6*k*). The preponderance of the 40–80 mesh fraction reflects the characteristic closely packed sand grains of medium size and moderate roundness which associate the ridge ferricretes physically with the

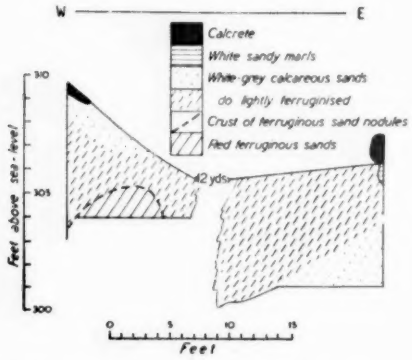

FIG. 9
Section through ferruginized zone in calcareous sand dune on Main Site, IH 72 in figure 3.

basal silver-grey sands described above. The cement consists of iron oxide and calcium carbonate forming between 20 and 25% of the whole and in the ratio of 1·5 to 1 or higher, indicating calcification as well as ferruginization of the original sands.

The ferricrete ridges are practically unfossiliferous—almost certainly unfossiliferous in depth; a few badly preserved, deeply ferruginized bones have come from the crests of the ridges, either cemented into the surface or lying loose but bearing an encrustation of ferricrete; stone implements have also been found under the latter circumstances. Since these anomalous finds can reasonably be explained as later inclusions, there is *prima facie* evidence that the formation of the ridges is not later than the period of fossil accumulation. Their true position in the history of the site may be sought from their relationships to adjoining surface deposits.

(*a*) *Relationship to calcareous dune sands and calcrete capping.* The calcareous dune overlaps the western ferricrete ridge at one point (fig. 3), at which a test trench gave the section reproduced in figure 9. The grading of the ferruginous sand 'hump', which is clearly a continuation of the ferricrete ridge to north and south, has more in common with that of the calcareous dune sands than with the normal ferricretes, as shown by the more prominent 40–80 mesh fraction (fig. 6*l*). Apart from a thin

encrustation of ferruginous nodules, there is no physical discontinuity between the normal and the ferruginized sands. This is taken to indicate that the narrow zone of ferruginization here passed into the calcareous dune, possibly near the slip face as shown by foreset bedding in the section. Upward enrichment in lime and downward enrichment in iron oxides left an impoverished intermediate zone of orange-brown sands (95% quartz). The ferruginous sands of the 'hump' in figure 9 also exhibit a smaller <80 mesh fraction and a lower iron content than the normal ridge ferricretes, suggesting that iron enrichment and cementation of the latter is partly consequent upon their exposure at the surface.

The calcareous dune sands thus appear to have *preceded* the ridge ferricretes; the stabilization of the calcareous dune and the formation of the calcrete capping, on the other hand, *postdate* the ridges as shown by the overlap in fig. 3, IH.

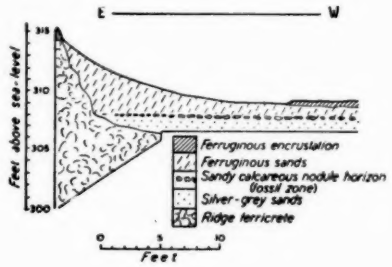

FIG. 10

Section into ferricrete ridge on Main Site, JH 67 in figure 3, showing relationships of ridge ferricrete to fossiliferous horizon and capping deposit.

(*b*) *Relationship to fossiliferous horizon and dark sand capping.* The relationship of the ferricrete ridges to these undoubted horizons is well exemplified in figure 10, which indicates that the ridges acted as limits or barriers within or against which the fossils accumulated on a definite level and that they played a similar role during the burial of the fossil horizon. This 'compartmenting' effect is brought out in the following table:

TABLE II

	Main Site		*Farmhouse Site*	
	(*a*)	(*b*)	(*a*)	(*b*)
	feet	feet	feet	feet
East of ferricrete ridges	309	315–20	302–3	311
Between ferricrete ridges	302	310	<290	292
West of ferricrete ridges	<290	>290	—	—

(*a*) is the altitude of the fossil horizon, (*b*) the altitude of the upper level of the capping deposit in feet above sea-level.

In any given area the fossiliferous horizon or capping surface shows a small range of altitude compared with the abrupt step-down westwards as one crosses a ferricrete ridge. This corroborates the sectional evidence that the ridge ferricretes are as old as or may partly antedate the fossil accumulation.

It is probable that the ridge ferricretes denote downward leaching below a sandy surface under a moderately high rainfall, possibly with contrasted wetter and drier

seasons, and a warm temperate thermal regime. Stagnant or sour ground-water environments in interdune depressions may also have induced bacterial precipitation of ferric hydrate from solution. The weathering, locally, of granites or of rocks of the Malmesbury Series might be looked to as a primary source of iron, but the immediate supply was most probably derived from the older dune sands of the Sandveld, for the presence of humic acids is still visibly sufficient to cause the removal of iron oxides and to lead to their concentrated re-deposition, with discoloration, at the ground-water level. This process is seen to be intensified at the base of sand-dunes in the area. It is accordingly suggested that during or prior to the encroachment of the calcareous dunes the seaward descent from the Sandveld Plateau was, in the area of the site, broken by sand-dunes trending NE.–SW. or N.–S., transverse to the regional slope. The disruption of drainage consequent upon the coastal dune invasion, possibly combined with a regional increase in rainfall, may have caused a rise of the water table sufficient to bring about the ferruginization of the lower cores of the 'Sandveld' dunes, particularly their upslope (eastern) flanks, and these were later stripped of their sand cover in the area of the site, hardening on exposure to form the ferricrete ridges.

The occurrence of ferricretes in areas near Hopefield largely bears out the deductions from the site itself.

Haughton (1932) describes a ferricrete between 3 ft. 6 in. and 5 ft. (1·1 and 1·5 m.) thick overlying unconformably the phosphatic sands at Langebaan Road. In some places it passes laterally into a band of ferruginous nodules in a sandy matrix, but it is apparently developed over a wide area, extending across the gently rising ground to the Vredenburg granite plateaux. It is locally capped by soft white tufaceous limestones. Ferricretes similarly cap the phosphatic sands in the valley of the Buffels River near Bok Baai (Haughton, 1933).

Ferruginous sand horizons are evident in the terrace sections of the Great Berg River north of the fossil site.

(*a*) On the farm Swartjies, on the left bank and less than 5 miles (8 km.) inland (fig. 1), dark silicified ferricretes overlie Malmesbury shales at 8 ft. (2·5 m.) above river level and slope downwards to continue out into the river bed. They are overlain to a height of 13 ft. (4 m.) above river level by fine quartz gravels containing struck flakes of Middle Stone Age affinities. These gravels contain rolled fragments of the basal ferricrete and possess a ferruginized upper horizon beneath a loose sand cover.

(*b*) Massive ferricretes both cap and underlie similar gravels in a right bank tributary at Sauer. These extend to a height of 51 ft. (16 m.) above the adjoining valley floor but contain débitage similar to the flakes in the Swartjies gravels.

Therefore at least two periods of ferruginization are indicated; one preceding and one postdating the Middle Stone Age.

Most significant are the ferricretes near the Buffels River mouth and 1 mile (1·6 km.) east of the farmhouse at Bok Baai (Mabbutt *et al*, 1955). They form ridges and platforms rising inland and disappearing beneath the mobile dunes making the cliff slope up to the limestone-covered coastal plateau. Seawards, they descend

between headlands planed at the 20–25 ft. (6–8 m.) raised beach level and terminate in a low bluff as little as 16 ft. (5 m.) above the present shore. Where eroded and discontinuous between the dunes, they are indistinguishable in appearance from the ridge ferricretes at Elandsfontein (Plate II B). Stone implements ranging typologically through the Middle to the Later Stone Age have been found on the ferricrete surfaces; these include small hand-axes characteristic of the Hopefield assemblage. The Bok Baai area is important as revealing massive ferruginization prior, at least in part, to the Middle Stone Age and yet extending down below the Minor Emergence shore level.

4. The Fossiliferous Horizon

Apart from their less frequent occurrence in and below the calcretes on the calcareous dune and in the surface limestones on West Site, deposits treated separately below, the fossils, with but few exceptions, are found on a definite and restricted horizon; excavation below this level has invariably revealed only sterile sands. The nature of the fossiliferous horizon varies with distance from the calcareous dune.

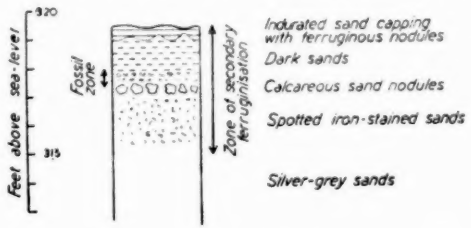

Fig. 11

Section through capping deposit and fossiliferous horizon in the east of Main Site, KH 97 in figure 3.

(*a*) *Zone of calcareous nodules.* Above the basal silver-grey sands on the eastern and southern parts of Main Site and above the more calcareous sands on Farmhouse Site, the fossils occur at the upper surface of a band of calcareous sand nodules (Plate IV A). The band is between 1 and 2 ft. (30 and 60 cm.) deep and the nodules range from 1 to 6 in. (2·5 to 15 cm.) across (average 2–3 in. (5–7·5 cm.)). A typical section is given in figure 11. The larger, more closely packed nodules are always near or at the upper limit of the zone, even forming a continuous crust locally, as on Farmhouse South. They are moderately hard and in a fresh exposure are khaki or yellow-brown in colour, subsequently weathering white or light brown. The nodules become progressively smaller, more scattered and darker in depth, while the underlying sands are commonly 'spotted' with small concretions of lighter coloured material for a distance of 2 ft. (60 cm.) and more below the nodular horizon. The surrounding sands are iron-stained in both the nodular and mottled horizons, the degree of staining decreasing downwards.

A section through a nodule which has been exposed for some time at the surface reveals an outer calcareous crust and an inner ferruginized ring, hard and compact, with an intervening leached zone of yellowish sand and a less cemented core of calcareous sand of the same colour. This profile repeats in miniature the section

given in figure 11, indicating ferruginization in an initially calcareous matrix followed by surficial calcification on exposure. The calcareous weathering crust is more marked on nodules coming from the upper part of the zone; the lower ones often retain a drab grey-brown colour.

The grading of the nodules resembles closely that of the underlying sand, except that the finest (>80 mesh) fraction is greater, due to the presence of intergranular cement (fig. 6*c*). The lime content is much higher than that of the parent sands—four times as high on Farmhouse South—the absolute enrichment being more marked near the calcareous dune.

One is clearly dealing with a surface and sub-surface lime hardpan, and the direction of concentration in the nodular zone points to cementation due to upward movement of calcareous soil solutions into a shallow, periodically aerated surface layer. Such would form on the drying out of shallow pans fed by ground water enriched in lime from adjacent calcareous sands. Bones lying on the pan floors would thus become cemented in and protected by the nodular limestone layer, which would provide an ideal fossilizing environment. Subsequent ferruginization has affected bones and nodules and has stained the sands both in the nodular zone and in an underlying mottled horizon of lime enrichment.

(*b*) *Ragged calcretes.* In areas immediately adjacent to the calcareous dune, particularly where the latter appears to have been most mobile, as on its north-eastern flank, the nodular horizon becomes more continuous and the fossils occur embedded in a ragged calcrete 1 ft. (30 cm.) thick overlying the calcareous sands. The ragged calcrete passes laterally into the massive calcretes on the calcareous dune, but it is also capped locally by a similar, though thinner crust. Its grading is that of the calcareous dune sands (fig. 6*j*), and its lime content (35–40%) is much greater than that of the nodules described above. It would thus appear to be the equivalent of the nodular zone, formed in a more lime-rich environment, with admixture of sand from the calcareous dune. Like the nodular zone, the ragged calcrete has undergone subsequent iron enrichment which has affected fossils and containing deposit alike. It might properly be described as a ferri-calcrete, and is light or even dark brown in section although generally developing a white weathering-crust.

It has been possible to reconstruct the contours of the fossil horizon on Main and Farmhouse Sites (fig. 12). These reveal a surface sloping westwards with a fall of 1 in 100 to the foot of the limestone ridge beyond West Site, and to this extent substantiate the deductions made from the physiography of the region. The descent is broken only by the calcareous dune, which lies transverse to the slope, and by the ferricrete ridges, which trend obliquely to it, whence their descent south-westwards. The barrier effect exercised by these ridges has already been referred to. Elsewhere the regularity of the contours is impressive, and it is noteworthy that extrapolation from Farmhouse West at the average rate of descent gives the correct altitude for the fossiliferous horizon on West Site. This regularity of slope is opposed to the concept of enclosed basins of any depth as foci of fossil accumulation, except, perhaps, in front of the calcareous dune ridges. The picture one receives is rather that of a fairly smooth sand slope traversed by braiding channels connecting shallow pans which might dry out seasonally.

5. Surface Limestone and Calcrete

(*a*) At the north-west corner of the largest of the hollows on West Site, immediately at the foot of the dune-covered limestone ridge marked in figure 2, the calcareous sands are overlain by a capping of limestone 1 ft. to 1ft 6 in. (30–45 cm.) thick, moderately indurated, marly in texture and of great purity (85–92% $CaCO_3$) (fig. 14). Cream or flesh pink when fresh, it weathers white and hardens on exposure.

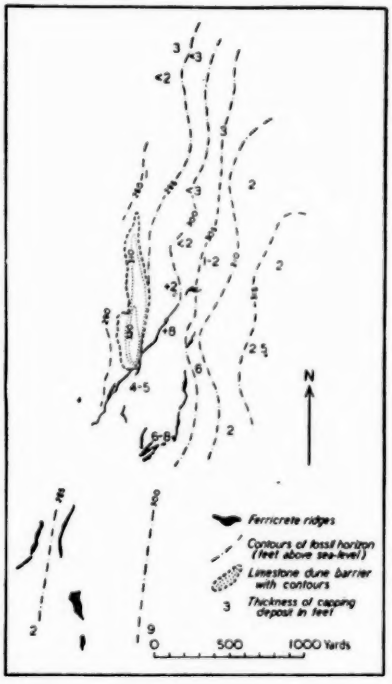
N
Ferricrete ridges
Contours of fossil horizon (feet above sea-level)
Limestone dune barrier with contours
Thickness of capping deposit in feet
0 500 1000 Yards

Fig. 12

Contours of the fossil horizon on Main Site and Farmhouse South, showing its even descent westwards and the varying thickness of the capping deposit in relation to the ferricrete ridges.

As far as the limited outcrop allows generalization, it occurs as a close mosaic of flat slabs 2–4 ft. (0·6–1·2 m.) across. Although it contains little coarse material, the large, well-rounded and frosted quartz grains seen in the underlying sands could be recognized, otherwise the contained sand grains show little frosting, low roundness (0·3–0·5) and but moderate sphericity (0·5–0·7); the physique is essentially that of a fine sediment (fig. 6*h*). The subjacent calcareous sands and, in less degree, the limestone have undergone subsequent ferruginization from above, the limestone locally being converted to a red-brown loamy marl. Fragments of fossil bone were found in this replacement horizon, while the jaws of a young rhinoceros were found *in situ* in the ferruginized calcareous sands immediately below the limestone.

Similar limestones occur on Farmhouse West (fig. 13), also along the western margin, and similarly overlying the fossiliferous horizon, which here is at a depth of 2 ft. 3 in. (69 cm.). The limestones were probably formerly extensive over this site. The upper surface shows slight secondary silicification and is corrugated in a N.–S. direction due to wind action. A cellular white calcareous sandstone 6 in. (15 cm.) thick directly overlies the fossil layer at the north-western corner of Farmhouse North; the deposit shows features transitional to the calcretes on Main Site (see 5(*b*)). Further level outcrops of white surface limestone occur on the farm Ratelfontein, 2 miles (3·2 km.) south of the site, and also near Langebaan Road (Haughton, 1932), where they overlie the ferricrete horizon already described.

The limestones described here clearly represent pan floor deposits adjacent to dunes of calcareous sand and were formed after the fossil accumulation by the drying

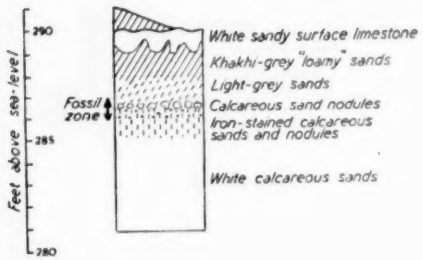

FIG. 13

Section through surface limestone and underlying fossiliferous horizon on Farmhouse West, HB 17 in figure 4.

out of calcareous muds enriched in lime by evaporation. The pans were in all probability dammed by the calcareous dunes, which, as already mentioned, lie athwart the regional slope and original drainage lines. One is undoubtedly dealing with a series of connected pans rather than with a single floor, for the horizon on Farmhouse West (285 ft. (86 m.) above sea-level) is 45 ft. (14 m.) higher than that on West Site only 1 mile (1·6 km.) distant.

(*b*) The calcareous dune ridge on Main Site owes its preservation partly to a hard capping of sandy limestone—a true calcrete—from 1 to 2 ft. (30 to 60 cm.) thick. Relict pillars and tabular masses attest to its former continuity above the fossiliferous horizon across the northern half of Homo Bay, while it also extends as a broad apron in front of the calcareous dune at its southern end. It is generally more calcareous (>50% $CaCO_3$) than the underlying dune sands and often contains thin wavy bands of pinkish tufa. Numerous shallow basins on its surface have been filled to depths of 6 in. (15 cm.) with successive layers of coarse sand and light brown limestone, the results of alternate wetting and drying. These 'fillings' are resistant to erosion and often cap remanié pillars of calcareous sand (Plate I A). At the northern end of the dune ridge are solution pipes 3 ft. (1 m.) deep and between 1 and 2 ft. (30 and 60 cm.) in diameter and filled with calcareous sand and calcrete breccia—the latter often fossiliferous—proving solution, fragmentation and re-cementation of the crust. Rootlet tubes occur in the same area. Encrustation and weathering must

therefore have proceeded over a long period subsequent to the stabilization of the dune and the emplacement of the faunal remains, eventually producing a continuous calcrete carapace which has since been undercut and extensively removed by sand blast. The calcrete shows some secondary silicification and moderate iron-staining, particularly of the less arenaceous horizons. A similar but thinner crust can be seen to underlie and to overlie fossiliferous sands on the northern limit of the dune—an older calcrete marking a temporary halt in sand accumulation during the period of fossil emplacement.

Massive calcretes occur on the ridge beyond West Site and on the limestone ridges and plateaux extending beyond to the coast. Du Toit (1917) describes from the Dorcasia Limestones a 'hard silicified and calcified upper surface with a peculiar wavy and banded structure' and 'surfaces much channelled by solution'; he also refers to a limestone breccia frequently underlying the calcrete capping. Such widespread solution weathering of the calcretes in the coastal limestone belt may be accepted as evidence of a more humid climate following the drier period postdating the fossil accumulation.

The calcretes appear to be continuous with the surface limestones described above, with the difference that they were formed in dune or sand spread environments above the level of temporarily standing water.

6. Capping Deposits

The fossiliferous horizon has subsequently been sealed by a capping deposit which on Main Site forms the 'floor' underlying the mobile dunes, and which, like the underlying fossiliferous zone, varies in character with distance from the calcareous dune.

(*a*) *Dark ferruginous sands*. On the eastern and south-eastern parts of Main Site and on Farmhouse South, in just those areas where the capping is thickest, grey-black sands extensively cover the fossils (Plate IV A). They have been dissected into low, level platforms by wind erosion. The section in figure 11 is characteristic, but on Farmhouse South the sands attain a thickness of 9 ft. (3 m.). The upper crust of the sands, 6 in. (15 cm.) thick, is harder and darker, with closely packed ferruginous sandy pisoliths; the sands below are loose and structureless and become lighter in colour downwards, but the iron-staining extends into the fossiliferous layer and underlying sands as already described. The sands consist of a small fraction of large (>20 mesh) grains of very pronounced roundness (0·9) and sphericity (0·7–0·9), together with finer (60–<80 mesh), subangular but equidimensional grains, and are thus texturally related to the underlying basal silver-grey sands (fig. 6*e*). The crust exhibits coarser grading, with a prominent 20–40 mesh fraction, and shows affinity with the basal sands of the vegetated dunes near by. The combined content of iron oxide and lime is low (5% on the average), but rises to 15–20% in the crust, due to iron enrichment. There is a small organic content and the deposit resembles a soil more closely than any other deposit on the site.

If we map the thickness of the capping it is made clear that the regularity which characterizes the fossil horizon is lacking (fig. 12). The thickness is fairly constant

at 2 ft. (60 cm.) in the north-east of Main Site but decreases to zero against the calcareous dune in the north-west; it increases southwards and south-westwards and attains its maximum against or between the ferricrete ridges; clearly the direction of sedimentation was along these lines. The effects of the ferricrete ridges on the altitude of the upper surface of the capping deposit are more marked than on that of the fossil horizon, emphasizing that the former is a true deposit *upon*, the latter an accumulation *at* a pre-existing surface. The barrier role of the ridges, and hence their antecedence, as shown in figure 10, is not readily apparent at the surface, for at many points the ferruginized upper surface of the capping runs smoothly into the ridge crests, as though the ridge were, in fact, merely its indurated up-swept margin. The relationship between the levels of ridge crest and capping crust is not, however, sufficiently constant to justify this view. For instance, from standing but 1 or 2 ft. (30 or 60 cm.) above the capping, the western ridge crest increases to 6 ft. (2 m.) higher at its northern end. Elsewhere the crest may lie lower than the capping near by. The section in figure 10 resolves this difficulty to some extent, for it indicates *two* periods of ferruginization. The later, minor one, which caused the formation of the ferruginous crust and the staining of capping deposit and fossils, has apparently caused secondary ferruginization of the ferricrete ridges, thus accounting for the surface continuity between the ridges and the capping deposit.

Van der Merwe (1941) has described the development of dark sandy soil as characteristic of depressions in the Hopefield area, and the character and thickness of the dark sand capping point to it having accumulated between or against dune barriers through rainwash, occasional stream flow and sand blowing. Although not necessarily representing a lengthy accumulation, it has formed a land surface over a long period, as shown by its weathering crust and by the occurrence upon it of occasional Middle Stone Age artefacts and more frequent Later Stone Age implements and pottery. It forms a single floor, continuous beneath and therefore antedating the mobile dunes on the site (fig. 7, G–H).

(*b*) *Cellular ferricrete capping.* In the north of Main Site, nearer to the calcareous dune, the dark sand capping described above thins to an average of 2 ft. (60 cm.) and passes into a level expanse of red-brown ferruginous sandstone 1 ft. (30 cm.) thick, cellular but hard, capping dark grey-brown sands. Texturally they resemble the dark sand capping, but, in accordance with their proximity to the calcareous dune, these cellular ferricretes possess a much higher lime plus iron oxide content (18–23%).

(*c*) *Ragged calcrete.* Traced north-westwards, the cellular ferricrete passes into the ragged calcrete or ferri-calcrete described in 4(*b*) above, and which embraces both fossiliferous and capping deposit as it is only locally overlain by calcrete similar to but thinner than that on the limestone dune. With increase in iron content, the ragged calcrete changes from a whitish to red-brown colour and grades into the cellular ferricrete. At one locality (fig. 3, JL 30), it passes laterally into brick-red ferruginous sand with an indurated crust, which has been dissected into yardangs by southerly winds. Although restricted areally, iron-staining is visible to a depth of 5 ft. (1·5 m.), below which the brown sands merge into grey sands which here form

the basal stratum. The texture of the hardened ferruginous sand crust identifies it with the ragged calcrete at the same level; the iron-stained sands beneath are similarly akin to the grey sands underlying the ragged calcrete. The lime plus iron oxide content is only 11% in the ferruginous crust as against 38% in the calcrete. Such laterally restricted iron enrichment is significant as indicating the mode of subsequent ferruginization generally experienced by the fossiliferous and capping deposits.

(*d*) *Massive calcrete and surface limestone.* On the calcareous dune on Main Site and over much of the northern part of Homo Bay the fossils are capped by or included in the massive calcrete described in 5(*a*). At lower levels these have undergone slight

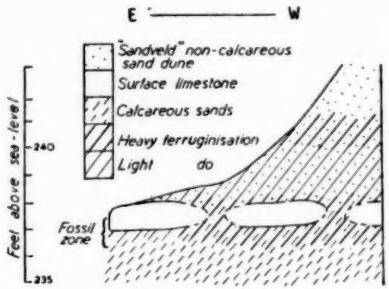

FIG. 14

Section on West Site, BD 19 in figure 5, demonstrating that ferruginization of the fossiliferous horizon has here proceeded beneath a dune cover.

ferruginization, the calcareous sands immediately beneath them even more so. The calcretes pass into surface limestones farther west; on West Site these cap the fossil floor directly, on Farmhouse West the fossil zone is separated from the limestone by 2 ft. 3 in. (69 cm.) of grey sands which become marly above (fig. 13).

The calcrete on the extreme northern flank of the limestone dune ridge on Main Site is at one or two points overlapped by the cellular ferricrete capping; it is thus clear that crustal calcification on the dune set in before the deposition of the capping was completed and before secondary ferruginization had set in.

The fossiliferous horizon and capping deposit almost everywhere exhibit subsequent ferruginization, generally most intense above the fossil layer, and which, as will be shown, was responsible for the mineralization of the bones. In figure 14 is shown a characteristic section on West Site, where ferruginization is seen at the base of the covering dune, extending down into and causing local alteration of the suface limestone and staining the underlying calcareous sands. This suggests a general explanation of the ferruginization west of the calcareous dune on Main Site, namely that the area was buried beneath a sand-dune cover from which iron was leached downwards, enriching and staining the deposits beneath. The remains of such a cover can be seen at the northern end of Homo Bay, where the massive calcrete is locally overlain by a soft, light brown, calcareous sandstone physically almost identical with the basal dune sand on West Site (fig. 6, *f* and *m*), although, as one might reasonably expect from the environment, the combined iron oxide and lime

content is higher (25% as compared with 16·5%). Iron staining extends down from the sandstones into the underlying calcareous sands. Only the crest of the limestone dune on Main Site has escaped significant ferruginization. The ferruginization *east* of the dune is regarded as the equivalent and contemporary process in a low-lying flat sand environment.

The hypothesis is supported by the noticeable iron-staining of the mobile dune sands on Main Site, which must represent sand stripped from the fossiliferous areas. They are, however, a concentrate, for their grading is coarser than that of the basal dune sands and brown sandstones already described (fig. 6*n*) and consequent upon the deflation of the finest materials the lime plus iron oxide content is very low (1·5%).

IV. Geological Setting of the Fossils

Reconnaissance investigation revealed that the exposed fossils formed a single layer which on Main and Farmhouse Sites was associated with white or light brown nodules of calcareous sand or more compact calcretes, and on West Site with a floor of surface limestone. In view of the wealth of fossils and the signs that more were continually being laid bare by wind blast, it was originally considered that they might represent a natural concentrate from one or more zones. It is possible that some such concentration has occurred by the wind-winnowing of an original sandy matrix, but the initial depth of any such deposit cannot have been great, since in *all* parts of the site trenching has shown that the fossils now occur in a single horizon in or at the upper limit of a zone of lime enrichment and that the underlying and overlying sands are sterile. Such absence of stratigraphic depth betokens a general lack of contemporary deposition unusual in a dune environment and *a priori* evidence that the fossil accumulation marks a single episode in the geological history of the site.

The essential unity of the fossil horizon as established on a stratigraphic basis is also indicated by the uniform fluorine and uranium content of a selected series of specimens from the site, including the human skull (Oakley, 1954, 1955). Some vertical 'spread' of the fossils may be observed on the limestone dune, where they occur in and down to 2 ft. (60 cm.) below the calcrete, but this is readily explained as due to the loose sand surface then existing. Many of the fossils in the calcrete are fragments in the fillings of solution hollows.

A small number of fossil fragments have, however, had an anomalous occurrence, having been found above the capping deposit and on the surfaces of the ferricrete ridges on Main Site. They are typically fragmentary and highly ferruginized and may conceivably have been derived by erosion of the main fossil horizon. They are not sufficiently numerous nor faunally distinct enough to affect the arguments on palaeontological grounds for the age of the principal fossil accumulation, but their occurrence is of interest in view of the archaeological evidence described below. Steps now being taken to obtain chemical data on a wider range of fossils, selected on faunal, stratigraphic and physical bases, may decide whether a second minor phase of fossil emplacement followed the concentration, cementation and, in part, the burial of the main fossil layer.

There are no systematic large-scale variations in the richness of the fossil layer with the exception of Farmhouse South and the south-eastern part of Main Site, which are poorer, these being areas where the capping is thickest and the underlying deposits have been least exposed and attacked by the wind, and also parts of the site where the original sands were least calcareous and the environment least favourable for the cementation and preservation of the bones.

In detail the exposed fossils generally lie in clusters, which commonly cap and protect low mounds of sand and calcareous nodules and each of which may contain the mixed and incomplete remains of numerous species (Plate III A). Allowing for some movement since exposure, there is strong indication of scattering of the bones after their initial emplacement and before cementation, but the movement was at most local, as shown by the amount of material and its excellent condition. One may occasionally recognize the almost complete remains of a single animal within an area of a few square yards and some limb bones remain in alignment, showing that no movement can have occurred since the original decay. These features jointly indicate restricted transport—certainly an absence of directional concentration—and negligible erosion at the time of fossil emplacement. Assuming the presence of water to be the reason for the faunal concentration and its seasonal or subsequent drying as the explanation of the associated surface calcification, this water cannot have been strongly flowing, as shown by the unrolled state of the fossils and the accompanying artefacts, neither are the slope and height range of the fossil layer on the site consistent with the existence in this area of a continuous body of standing water of any magnitude. The environment suggested is rather a series of shallow, sand-trapped pools and channels undergoing seasonal fluctuations in volume; the fossils on their floors, becoming encased in surface limestone, would be naturally protected against serious erosion, although it is possible that wind action may first have led to lowering, locally, of exposed sand surfaces and the concentration at a single level of the contained fossils.

In Table III the mineral composition of fresh animal bone (*a*) is compared with that of two pieces of fossil bone from Main Site, the one (*c*) exhibiting deeper iron-staining than the other (*b*).

TABLE III

	a.[1] % wt.	b.[2] % wt.	c.[2] % wt.
CaO	53·2	44·9 (50·5)[3]	45·5 (51)[3]
P_2O_5	39·5	37·4 (40·2)[3]	36·0 (40·5)[3]
CO_2	4·6	3·0	3·3
F	1·0	2·0[4]	2·0[4]
Cl	0·6		
Na_2O	0·7		
MgO	0·9		
H_2O (combined)		5·2	4·0
Fe_2O_3		5·0	6·4
SiO_2		0·4	0·6
P_2O_5:CaO [5]	·83:1	·91:1	·86:1
$CaCO_3$	10·5%	5·8%	7·5%
CaF	3·9%	7·8%	7·8%

NOTES:

[1] Based on J. C. Brash and E. B. Jamieson, *Cunningham's Text-book of Anatomy*, eighth edn. Oxford University Press, 1943, p. 94.

[2] Based on analyses by Dr. E. G. Manken, Cape Town.

[3] Recalculated percentages after removing iron, combined water and additional fluorine.

[4] As given in Oakley (1954).

[5] Removing $CaCO_3$, assuming CO_3 present as $CaCO_3$.

If the loss in calcium carbonate be offset by increased calcium fluoride, the phosphate : lime ratio in the fossils is only slightly higher than that in fresh bone, and this is reasonably explained if a small amount of phosphorus is present as ferric phosphate. Apart from these slight changes, mineralization appears mainly to have involved the replacement of organic matter by ferric hydrate; the recalculated percentages of CaO and P_2O_5 in the fossils after removing the iron oxide, combined water and additional fluorine approximate to those of fresh bone. The lack of enrichment in calcium phosphate is surprising in view of the environment and indicates that mineralization occurred during the period of ferruginization *after* the formation of the nodular calcrete in which the fossils are cemented.

V. Rounded Boulders on the Site

A remarkable feature of the site is the occurrence, on the fossiliferous floors, of cobbles and small boulders of rocks of various types which are listed below, together with their possible geological origin and the range of elevations of the nearest outcrops:

(*a*) Quartz-porphyry and Grey Granite

From the Cape Granite, which builds hills 5 miles (8 km.) to the north-west (Massenberg), 350–528 ft. (107–161 m.), and to the south-west (Betjieskop), 400–750 ft. (122-229 m.).

(*b*) Lydianite, Hornfels, Dark Blue Quartzites and Flagstones

Probably from the Malmesbury Series; the nearest outcrops occur in the valley of the Sout River, 6 miles (10 km.) across the low watershed east of the site, 25–150 ft. (8–45 m.), on the coast in Saint Helena Bay, 20 miles (32 km.) to the north-west and at Yzerfontein, a similar distance to the south-west.

(*c*) Vein Quartz

Probably from the Malmesbury Series, possibly from the Cape Granite.

(*d*) White, Blue-Grey and Reddish Quartzites

Most probably from the Table Mountain Series, the nearest outcrop being Piketberg, 300–3,000 ft. (92–915 m.), 25 miles (40 km.) to the north-east across the Great Berg River.

(*e*) White or Light Grey Chalcedonic Quartzites, ranging from Fine-grained Types to Breccias

Outcrops occur in the valley of the lower Great Berg River, 15 miles (24 km.) to the north of the site at *c.* 50 ft. (15 m.), on the plateau near Darling, 15 miles (24 km.) to the south-east at 250 ft. (76 m.) and beyond Hopefield at Koperfontein, 10 miles (16 km.) east, at approximately the same elevation.

(*f*) Smaller Fragments of Chert, Chalcedony and Jasper, largely as Débitage

Source unknown.

The bulk of the material in groups *a*, *b* and *d* and a small fraction of that in group *e* is rounded, with a notable proportion of discoidal boulders with the chattermarks so characteristic of beach gravels. All types—even the crystalline rocks—are represented among the artefacts from the site, although implements made from type *d* are commonest.

The distribution of the boulders is essentially that of the fossils and artefacts. The upper surface of the capping deposit and the crests of the ferricrete ridges and limestone dune have yielded small flakes of chalcedony and occasional quartzite and granite boulders, these latter often employed as grindstones or used in the crude Later Stone Age artefacts found at these levels. As with the implements, however, there can be no denying the appearance of the boulders in increased numbers wherever the fossil horizon has been exposed, although this association has yet to be proved by sectioning. The boulders appear to be more than usually numerous at the southern end of Homo Bay and in the northern depression on West Site.

The occurrence of the boulders must be satisfactorily accounted for in any reconstruction of the palaeogeography of the site, and the range of possibilities is critically reviewed below:

Beach deposit in situ. This is opposed by the association of the boulders with the fossils, which are presumed to be a single deposit, at heights ranging from 240 to 310 ft. (73 to 95 m.) above sea-level, by the nature of the containing deposits and by the proportion of unrounded silcrete boulders.

Old beach gravels at the bases of island hills to the north-west and south-west of the site redistributed by streams following drainage diversion by the coastal limestone dunes. While a more cogent explanation for the boulders on West Site, it cannot apply to those on Main Site, which are up-slope from such potential sources of supply and the presumed drainage lines.

River gravel in situ. The granite which has supplied many of the boulders lies down-slope from Main Site, while the obvious beach boulders remain unexplained.

Carried by man from a river gravel occurring locally. This could account for some of the boulders, although the physical setting of the site renders it unlikely that a river gravel with the complete range of rock types from the site could occur locally.

Carried by man from present or raised beach deposits to the west of the site. This explanation is accepted, *faute de mieux*, for the obviously wave-shaped discoidal boulders. It is conceivable that old beach or river gravels, no longer visible, may have been exposed in the neighbourhood at the time of the occupance of the site by Palaeolithic man.

Collected by man from outcrops near the site. Although none has been found in the immediate vicinity, it is likely that outcrops of silcrete, now dune-covered, closer to the site than those named above, provided the raw material for the bulk of the artefacts.

VI. The Artefacts and their Geological Setting

The geological context of the artefacts is somewhat less satisfactorily known than that of the fossils, but there is good evidence that the bulk of the implements occurs together with the fossils; their relative abundance from place to place on the site and the circumstances of their exposure are closely related. Disregarding the Later Stone Age forms, the assemblage of implements comprises two classes, namely a rich collection of the final stage of the hand-axe sequence in the western Cape Province in addition to a smaller, classic series of the Stillbay culture, the two groups exhibiting a technological continuity despite differences in the finished products.

A study of *état physique* emphasizes the above division, the Stillbay series being little worn and generally little patinated, although sometimes exhibiting iron-staining. No subdivision of the older group is possible on the basis of physical condition; none of these implements has been rolled, but most have been sand-blasted on one or more faces; a few specimens suggest water glazing; artefacts manufactured from chalcedonic quartzite characteristically exhibit a cream-coloured or

light brown patina, while others, of less stable materials, are frequently much leached. These differences, however, cut across any typological subdivision within the group and, less sharply, across a division based on lithology; the surface weathering shows all the variability consistent with a dune environment. Many of the implements of this group are encrusted with hardened calcareous sand, indicating their provenance from the fossiliferous layer of calcareous sand nodules, and hand-axes have been observed in process of being eroded out from this horizon (Plate III B). The age of these implements is thus crucial to the dating of the fossils and of Saldanha Man.

Despite the separation of the Stillbay artefacts on typological and physical grounds, they normally occur exposed together with the older implements; the upper surface of the capping deposit is found virtually barren of implements adjacent to exposures of the underlying floor bearing artefacts of both classes in abundance, indicating that almost all the Stillbay assemblage occurs in or beneath this deposit. This has been substantiated by test sections at figure 3, KH 97 and on Farmhouse South, where flakes showing advanced prepared platform technique were recovered from immediately above the fossil horizon, and at figure 3, JG 67 (fig. 10), where an 'oak-leaf' or serrated point of undoubted Stillbay affinity was found at the same level. These implements occurred loose in the sections and showed an absence of limestone encrustation. There is good evidence, therefore, that although what is typologically most advanced in the stone-work is geologically closely associated with the fossil-cum-hand-axe horizon, it was apparently never cemented into that horizon nor subjected to the severe sand-blasting and weathering of the older material prior to its burial. We must regard the main fossil assemblage and associated artefacts as antedating the Stillbay culture on the site.

A few Stillbay implements, some partially encrusted with ferruginous sands, have been found on the ferricrete ridges above the level of the capping deposit; others have come from the upper surface of this deposit, particularly in the south-eastern quarter of Main Site. Less than one hundred pieces of worked stone are reported as coming into this group, but their anomalous occurrence deserves consideration, particularly in view of the parallel distribution of a minority of the fossils. It may be stated in partial explanation that under the interpretation favoured by the writer the ferricrete ridges must have marked higher ground before and after the formation of the capping deposit and that implements and fossils may subsequently have been redistributed from them to lower levels adjacent. However, the capping may indeed have formed relatively rapidly and prior to the end of the Stillbay period; the condition of implements of this culture certainly argues against any long exposure.

The older implements have been manufactured from a variety of rocks, comprising silcrete of varying coarseness, chert, jasper, vein quartz, quartzite, flagstone, lydianite, hornfels, quartz-porphyry, granite and lamprophyre (Plate IV B). No outcrop which could have supplied any of these materials has been found on the site, nor have any of the surface deposits been utilized. The range of the materials is that of the rounded boulders described above, which it is considered have supplied

much of the stone for the manufacture of the hand-axe assemblage, plus a fine-grained silcrete, which on many of these older implements bears a rough white outer surface or a light brown patina. The Stillbay implements, on the other hand, comprise a narrower range of materials, crystalline or coarse-grained varieties being absent, and there is a marked preponderance of the fine-grained silcrete, which in these later specimens may retain the mottled grey-brown colour of the fresh rock. The emphasis may reflect the demands of more refined flaking techniques, but it may also indicate the non-availability of other raw materials owing to cementation and partial burial of the fossiliferous horizon prior to the Stillbay occupation.

In an attempt to trace the source of the silcrete used in all types of implement from Elandsfontein, a specimen was examined by Mr. S. Amdurer of the Department of Geology, University of Cape Town, who has kindly reported upon it as follows:

'The rock is a fine-grained silcrete in which occasional large, sub-crystalline quartz grains can be seen with the naked eye, as well as the voids so typical of silcretes. It is basically light grey in colour but is stained orange-yellow throughout. It is slightly polished and rounded where weathered.

'It is seen in thin section to consist essentially of sub-angular quartz with a scattering of highly angular and a few rounded grains. No feldspar was noted, but occasional particles of limonite were seen, and a very few well-rounded zircons and needles of rutile were observed. The matrix consists of crypto-crystalline chalcedony with the iron-staining visible in the hand specimen. The staining is seen to consist of non-crystalline, translucent material disseminated throughout the groundmass and sufficiently concentrated locally to be visible to the naked eye. It is likely that these denote inclusions of clay particles on which iron oxides have been absorbed.

'Due to its highly variable nature, silcrete cannot generally be identified as to its place of origin. Howevèr, the specimen resembles most closely silcretes found above the Dwyka Series as described by Frankel and Kent (1937).'

Because of its low content of rounded quartz grains, this silcrete is unlikely to have been derived from any of the surface deposits on the site; it might reasonably be attributed to surface silicification on an outcrop of the Malmesbury Series. Visits were made to all mapped silcretes occurring above Malmesbury beds in the region, but no fine-grained variety closely resembling that from the site was found. Chalcedonic quartzites occur above river gravels 20 ft. (6 m.) above the Diep River at Kalabaskraal and also above the Malmesbury Series at Koperfontein, 10 miles (16 km.) east of the site. The nearest known silcrete outcrop to Elandsfontein occurs 2 miles (3·2 km.) north of Darling, probably near the granite contact with the Malmesbury Series. This is an unusual band of silcrete resembling a silicified fault breccia; it may have supplied some of the chalcedonic breccia occuring at the site, but not the finer-grained varieties most typically used in the manufacture of the implements.

VII. The Geological History of the Site

Stage 1

The history of the site and adjoining area begins with the emergence, probably extending into the Kageran, of the wave-cut portion of the coast plain

referred to above as the Sandveld Plateau, which was fashioned with a sea-level approximately 300 ft. (92 m.) higher than at present. Much of this outer portion was surfaced with quartz sands of unknown thickness, the products of erosion of the Table Mountain Series and of the older rocks of the hinterland.

Stage 2

Spasmodic emergence continued during the Kamasian and Kanjeran due to a combination of glacio-eustatic oscillations of sea-level and continuing continental uplift and resulted in

(*a*) sharp incision by the through-flowing Great Berg River and its tributaries, the master drainage system which was extended across the newly emerged plain and which may at this period have found an outlet south of the Vredenburg granite plateaux into the Saldanha estuary;

(*b*) the development of shorter and more open westward-directed valleys consequent on the steep marginal slopes of the Sandveld Plateau, a development indicating a wetter regional climate than at present;

(*c*) the formation of a succession of lower marine terraces, well seen inland from Saldanha Bay, notably at 150–200 ft. (45–60 m.) and at approximately 50 ft. (15 m.) above sea-level, this latter in all probability representing the Major Emergence of Krige (1927);

(*d*) the linking to the mainland of the former granite island groups which rise from the lower coastal platforms flanking the Saldanha estuary.

Stage 3

Emergence continued to below present sea-level, for whereas Saldanha Bay is cut into the Major Emergence platform the later beaches follow the outlines of the embayment. Dating from this emergence, possibly beginning with a sea-level 105 ft. (32 m.) above the present if the phosphatic sands at Langebaan Road have been correctly interpreted as estuarine or lagunal, the coastal tract between Yzerfontein and Saldanha was invaded by calcareous shelly sand-dunes, an invasion probably motivated by the continuing shallowing offshore. Near the coast these sandy calcareous sands eventually dominated the topography, forming low plateaux and parallel dune ridges; farther east they invaded the valleys and buried the lower granite hills, giving rise to a more complex landscape. Former valley outlets were closed, notably that leading from Elandsfontein through the gap south of the Massenberg hills to the head of Langebaan Lagoon, which must formerly have constituted an important line of drainage for that part of the Sandveld Plateau lying to the east. It was through this gap that the coastal dunes achieved their maximum advance landwards; the foremost outlier traverses the site, 10 miles (16 km.) inland and only 2 miles (3·2 km.) short of the crest of the slope to the plateau surface and the low watershed to the Sout River valley. Elandsfontein marks the passage from the white calcareous sands to the silver-grey quartz sands of the Sandveld; the margin of the Sandveld Plateau here may originally have consisted of a westward-sloping sand surface traversed by low, somewhat irregular sand ridges 15–20 ft.

(4–6 m.) high and with a northerly or north-easterly trend, slightly oblique to the coastal dunes which trend north or north-west, parallel with the Atlantic Coast.

The depth of penetration of the littoral dunes and the effective disorganization of surface drainage from the Sandveld were probably facilitated by a drier climate during part or parts of this period, in contrast to the conditions prevailing during *Stage* 2, a view which also finds support in the lack of leaching undergone by the calcareous sands. Analyses of these sands on the coast and at the site show a comparable lime content, and the transition to the non-calcareous sands of the Sandveld appears to be the result of thinning landwards rather than of leaching.

The period of accumulation of the calcareous sands was long and persisted into the Gamblian, for it embraced the recovery of sea-level which is marked by the 20–25 ft. (6–8 m.) Minor Emergence raised beach and which led to the drowning of the Saldanha estuary and the isolation of the low granite islands in the vicinity. The outlines of the estuary and the lagoon have been determined partly by the former drainage pattern, partly by the disposition of the granite island masses and partly by the trend of the littoral dunes and the associated shore features. At many points along the coast the shelly sand or Dorcasia Limestone Formation is seen to overlie and thus to postdate the Minor Emergence shoreline and to extend as aeolian dunes below present sea-level, thus marking a second regression.

Stage 4

The blockage of drainage resulting from the dune invasion must certainly have favoured the formation of pans along its landward margin; although there appears never to have been a large, permanent water body on the Elandsfontein site, probably because of restricted available catchment, porous surface deposits and prevailing aridity. At some period after the emplacement of the calcareous dunes, however, the water table on the site stood higher than at present, as shown by the ferruginization of the lower cores of the Sandveld dunes to form the ferricrete ridges. These may have been vegetated sand ridges traversing and marginal to a series of shallow pans on a sand surface sloping westwards to the foot of the limestone ridge bordering West Site and here marking the general eastward limit of the littoral dune belt. That this ferruginization reflects a regional change to a wetter climate and not merely localized interference with drainage is indicated by the widespread occurrence of ferricretes in the area, where the present rainfall is inadequate for their formation, particularly on the Atlantic coast and in the lower Great Berg River valley, where they are seen to postdate the fall of sea-level from the Minor Emergence beaches and to be overlain by artefacts characteristic of the Elandsfontein assemblage.

Stage 5

The accumulation of fossils is regarded as falling in this humid period, for which an early Gamblian age is postulated. Comparable faunal remains from elsewhere in the region suggest that a bush-steppe environment with pans existed at this time over much of the coastal limestone tract and, there is reason to believe, for some distance seawards of the present shoreline. The occupation of the site by

Saldanha Man, who appears to have carried there, possibly from near-by occurrences, the water-worn boulders and silcrete fragments from which were fashioned implements marking the final stage of the hand-axe culture, must also be placed in this stage on the evidence of fluorine analysis as on geological grounds.

Stage 6

The concentration of fauna at certain points may itself indicate the onset of a period of desiccation which ensued, a period in which crustal calcretion of the now stabilized and vegetated coastal dunes set in, and when horizons of calcareous nodules, cellular calcretes or, in more lime-rich environments, true surface limestones formed over the former pan floors, encasing and protecting the bones and associated artefacts although these may have undergone some concentration at a single level by pene-contemporaneous wind erosion. The continuance of the drier period may be expressed in a slight resumption of sand movement.

Stage 7

The lower ground west of the calcareous dune on Main Site had already been buried beneath redistributed grey 'Sandveld' sands when moister conditions set in once again, fixing the sand-dunes and causing the sanding and silting up of interdune areas. Sedimentation of this type took place on Main Site and Farmhouse South, mainly upslope from the barriers constituted by the ferricrete ridges and the calcareous dune. The distribution and physical condition of the Stillbay implements point to their emplacement shortly prior to and during the early part of this period of sedimentation, which may thus be dated as Middle Stone Age, and a minority of the fossils may well relate to this same phase. There is, however, on typological evidence, no necessity to argue a long hiatus between this and the earlier period of human occupation. Moister ground conditions brought a resumption of ferruginization which darkened the capping deposit and extended down to the underlying calcareous horizon, mineralizing the contained bones. Ferruginization of the calcareous sands and surface limestones also proceeded beneath the sand-dune cover in Homo Bay and further west. Heavier rainfall caused solution weathering of those parts of the limestone dune ridge rising above the sand cover, the formation of shallow depressions and solution pipes in the massive calcrete crust and some silicification of exposed surfaces.

Stage 8

With reversion to the drier conditions which now characterize these coastal lowlands, dune movement was resumed and the Elandsfontein site was largely buried beneath its present sand cover. This final phase carried us into a recent period as shown by the occurrence of Later Stone Age materials on the surface of the capping deposit beneath the mobile dunes on Main Site.

VIII. Climatic Change

The relationships between past climates and associated superficial deposits are by no means fixed, for the latter must reflect soil moisture conditions which locally

need not necessarily be a function of climate. This is particularly true of a dune environment, in which rapid and frequent changes in the details of surface form and hence of sub-surface drainage are to be expected. The Hopefield site must accordingly be studied in its wider setting, emphasis being placed on the regional occurrence of surface deposits, whereby localized drainage effects are eliminated. In this area the annual evaporation from a free water surface is in the neighbourhood of 50 in. (127 cm.) (Levinkind, 1940), the mean annual rainfall less than a quarter of this amount, conditions leading to upward calcification and the production of surface or sub-surface limestones such as appear now to be forming in the Hopefield-Langebaan sandveld. This must be borne in mind when interpreting the palaeo-climatic evidence for successive stages in the geological history of the site in terms of the present climate.

Evidence has been brought to show that the Sandveld Plateau is a marine terrace dating back into the Upper Tertiary. It will be seen from the contours in figure 2 that its outer slope bears an integrated drainage with deep sub-mature valleys, reflecting a competence which is lacking in the present drainage and indicating that, subsequent to the emergence of the Plateau and during a period embracing the higher sea-levels of the Kageran and Kamasian period, the rainfall was heavier than at present, even allowing for drainage deterioration due to increased porosity of the surface cover. This evidence is not restricted to the Sandveld south of the Great Berg River; the dry channels of the Namaqualand Sandveld near the Olifants River mouth are graded to the level of the Major Emergence, testifying to the recency of desiccation in the area. It may be noted that the west coast Pleistocene shell beaches prior to the Minor Emergence (i.e. pre-Gamblian) contain warm water forms, pointing to at least a temporary modification of the cold oceanic currents which foster the aridity prevailing in this coastal belt.

The factors controlling littoral dune invasion are complex, but such widespread movement as that forming the calcareous sand ridges along this sector of the Atlantic coast demands some general cause. A partial reason may have been the current emergence of the coast, but the depth of penetration, the complete disruption of the drainage, the apparent lack of leaching of these coastal limestones and their content of the desert-inhabiting land snail *Trigonephrus* together point to a drier climate. Since the invasion covers a long period, more than one climatic oscillation may be involved; one can merely observe that the Kanjeran period brought generally drier conditions, remarking that the Minor Emergence (20–25 ft. or 6–8 m.) and later beaches already exhibit the cold water fauna which now characterizes this coast.

The regional aspect is most important in the climatic interpretation of the ferricretes, for while the local rainfall is inadequate to allow widespread ferruginization, local enrichment in iron may occur with arrested drainage, as is likely among sand-dunes. The examples cited above are considered sufficiently widespread and their geological and physiographical relationships sufficiently consistent to allow the postulation of a major period of ferruginization in the Sandveld. At Elandsfontein it follows the emplacement of the calcareous dune, since it affects it locally, but it is not later than the fossil accumulation. At Bok Baai the ferricretes are seen to post-

date at least the earliest stages of regression from the Minor Emergence beaches, and at Yzerfontein the cliff sections reveal a ferruginous zone at the base of the calcareous sands overlying the raised beach of the same age. The evidence from the lower valley of the Great Berg River similarly indicates that we may correlate this moister period with a time of falling sea-level, possibly a regression to below its present level, and possibly to be correlated with the final glacio-eustatic regression of the Pleistocene.

As additional evidence of former moister conditions along the arid west coast one may cite the existence of diatomaceous earths in what is now true desert, at Kannikwa, near Port Nolloth (Kent and Rogers, 1947), and the widespread occurrence in the Namaqualand sandveld north of the Olifants River of ferruginous sandy soils which led van der Merwe (1940) to conclude 'judging from the soil formed, it would seem that there has been a change to a drier climate along the coast, because it is hardly conceivable that the soil . . . could evolve under 5 inches of rain'. The accumulation of fossils is regarded as a phase of relatively short duration within, or towards the close of, this moister period. The faunal assemblage is typical of a bush-steppe environment and similar to that found, for example, in the Kaokoveld of South West Africa under a rainfall slightly greater than that now received at Elandsfontein, although forms such as Hippopotamus and *Kobus leche* indicate lacustrine or marsh conditions locally.

The formation of the calcareous horizons and the cementation of the fossils therein imply a reversion to drier conditions following the period of ferruginization. The occurrence of calcareous tufa overlying ferricretes in the vicinity of Langebaan Road (Haughton, 1932) is corroborative of this sequence. The continuance of the trend is shown by the encrustation of the limestone dunes over a wide area, although this process may also have occurred in both earlier and subsequent drier periods.

After the drier phase of calcification, sand deposition followed, as dune sands in the west of the site and as a level sand spread in the east. This deposition was associated with and terminated by increasing rainfall at the close of the Stillbay period, as indicated by the occurrence of a second, minor period of ferruginization within and below the sand capping, causing the mineralization of the fossils. Dark sandy horizons resembling the capping deposit at Elandsfontein are known from a wide area; at Bok Baai they occur seawards of and at a lower level than the older ferricretes described above, and are capped by unconsolidated sand-dunes with Later Stone Age middens. The peaty sands of the Cape Flats, which are likewise associated with the Stillbay culture, are comparable deposits under a similar environment. Although not necessarily bespeaking a heavy rainfall, this second phase of ferruginization must signalize a change to a moister climate after the conditions preceding. The same change is apparently reflected in the solution weathering and surface silicification of the calcrete capping of the limestone dunes on Main Site and in the adjacent coastal belt.

The final climatic oscillation would seem to be a reversion to the drier conditions now prevailing and with this change the further burial of the fossil site beneath its sand-dune cover.

On the assumption that the winter-rainfall area might exhibit in reverse the Pleistocene climatic rhythm of the tropical and summer rainfall regions, Oakley (1954) has suggested that the increasingly dry conditions following the ferricretes and during the early part of which the fossils accumulated might be correlated with the onset of the Gamblian pluvial of East Africa. The seasonal incidence of rainfall need not be relevant to the timing of pluvial fluctuations, however, nor does the writer consider that evidence from the winter-rainfall area justifies this assumption. There is good evidence that the main ferricretes, which antedate the fossils, come with a falling sea-level closely following the Minor Emergence beaches, evidence which would relate this moister period to the first peak of the Gamblian pluvials in East Africa. The second period of ferruginization would then mark the Gamblian II peak; its association with the Stillbay culture is in keeping with this view and with the postulate that climatic changes in the winter-rainfall area have paralleled those in East Africa. In Table IV is set out an interpretation of the climatic sequence at Elandsfontein based on this postulate.

TABLE IV

Reversion to semi-aridity.	post-Gamblian.
Second period of ferruginization.	Gamblian II.
Calcification. Stillbay culture.	Intrapluvial dry phase.
First period of ferruginization. Accumulation of fossils and hand-axes.	Gamblian I.
Drier phase of calcareous sand emplacement.	Interpluvials preceding Gamblian.

Although the evidence of climatic change is real enough, it cannot be claimed that the sequence of and timing of such changes in the winter-rainfall area are sufficiently known to justify their use as primary dating evidence in preference to palaeontological or archaeological probabilities where these conflict.

The factor of aridity as affecting the relative durations of wetter and drier periods must also be considered. In East and Central Africa the earlier interpluvial periods are relatively short and well defined, the pluvials are longer, and therefore less definite time-markers. In sub-humid areas such as the Vaal River valley and increasingly in the truly arid parts of the sub-continent, this inequality is reversed; the erosional effects of the relatively short pluvials and the deposits of their declining stages are characteristically buried beneath Kalaharian deposits or separated by well-defined zones of arid weathering. In the dry coastal lowlands near Hopefield, with no major exogenic drainage such as the Vaal, the signs of pluvial conditions tend to be even more heavily outweighed by the effects of the longer interpluvials, a reversal of emphasis which must inevitably exercise an important effect on chronology as set by climate and which may also have affected the spread and local development of Palaeolithic cultures. For instance, the onset of drier conditions accompanying fossil accumulation at Hopefield may have occurred earlier than the corresponding oscillation in East Africa, and, conversely, the moister period which follows the Stillbay on the site could have set in later.

IX. Dating

The dating of the sequences outlined above, and in particular the position of the Kanjeran-Gamblian boundary, is of extreme importance in view of the palaeontological and archaeological problems raised by the Hopefield site. The dating evidence can be summarized under the following heads:

Physical Anthropology. Here we find some divergence of views. Singer (1954) has compared the Saldanha skull with the Upper Pleistocene Rhodesian (Broken Hill) and Florisbad skulls, both of which have Middle Stone Age lithic associations, and has concluded 'the Saldanha skull is akin to a similar region of the Rhodesian skull; such differences as have been mentioned . . . may be regarded to fall within the limits of individual variation'. Drennan (1953), while acknowledging the close resemblance, regards the variations as more important and claims 'that Saldanha Man belonged to an earlier and more primitive variety of the Rhodesian race' to be associated with the final phase of the African Chelles-Acheul or hand-axe industry and conceivably to be placed at the end of the Middle Pleistocene.

Palaeontology. The geological homogeneity of the fossil assemblage stands in marked contrast to its diversity from the palaeontological viewpoint, for we find such archaic forms as *Mesochoerus*,* *Sivatherium* and *Palaeoloxodon* associated with the more advanced *Equus* cf. *capensis* and *Bubalus* sp. nov., together with numerous extant species. Cooke† has remarked upon the affinities of the faunal assemblage with that from Olduvai or from the middle phase of the Younger Gravels of the Vaal River (Cooke, 1949), and has claimed that the fauna appears older than that of Florisbad and Vlakkraal (Wells, Cooke and Malan, 1942). He concludes: 'even if allowance be made for the possible survival of archaic forms . . . the fauna cannot be regarded as significantly later than the final fauna of Olduvai or Younger Gravels II and III of the Vaal River. In terms of the East African succession it could hardly be younger than late Kanjeran and almost certainly not Gamblian'. The existence at Hopefield of what are elsewhere regarded as Kanjeran forms need not necessarily be contradictory if we consider the tendency in Africa for such survivals to occur and also the remoteness of the site at the south-western extremity of the continent. Singer would stress the absence of archaic types such as *Hippopotamus gorgops*, *Hipparion*, *Chalicotherium*, *Deinotherium*, *Mastodon*, etc., which would exclude it from the Kamasian, and also the non-appearance of *Archidiskodon*, which is represented in the earlier phases of the Vaal River gravels. The extinct faunas of Florisbad and Hopefield are not, in his view, sufficiently similar to justify comparison. He would 'conservatively place the Elandsfontein fauna into the equivalent of the interpluvial phase between the Kanjeran pluvial and the first Gamblian pluvial'. This, by recent definition, would also be regarded as late Kanjeran, and might imply a slight revision of an earlier published view that 'the total faunal assemblage suggests an early Upper Pleistocene period' (Singer and Keen, 1955).

* The newly specified *Mesochoerus lategani* at Hopefield is regarded by Singer and Keen (1955) as more advanced than the Middle Pleistocene *Mesochoerus olduvaiensis*.

† The writer is grateful to Drs. H. B. S. Cooke and R. Singer for permission to reproduce here views expressed by them *in litteris*.

Archaeology. As already stated, the older assemblage of implements is regarded as contemporary with the fossil accumulation. These are regarded by Jolly* as marking the final phase of the Stellenbosch culture at the Cape, the absence of the typical cores of the Vaal River sequence excluding them from the Fauresmith as known there. This does not necessarily imply a pre-Fauresmith age, however; considering the non-appearance of the type Fauresmith in the south-western Cape Province and the close physical association and technological affinity of the final hand-axe forms with the Stillbay culture in this region, it is a logical inference that the developed hand-axe industry completely bridged the gap from the Earlier into the Middle Stone Age, i.e. persisted into the Gamblian, which is accordingly regarded as the age of the fossiliferous layer on archaeological evidence. In stressing the technological unity of the whole assemblage, Jolly would allow of no separation of what have here been described, on geological grounds, as two separate groups of artefacts with the Stillbay assemblage distinctly, if not considerably, more recent and disassociated from the fossil fauna. In terms of age, the difference between these views need not be great; Jolly's interpretation merely places the fossiliferous layer later in the Gamblian.

Surface Geology. The ridge ferricretes, which antedate the fossils, have been shown to coincide with an early stage in the withdrawal from the 20–25 ft. (6–8 m.) raised beach. This higher sea-level is probably equivalent to the Late Monastirian beach in the Mediterranean, which in turn is regarded as either preceding or following the Wurm I glacial phase (?=Gamblian I of East Africa), and if either these views be followed, the ferricretes cannot be placed earlier than the beginning of the Gamblian. The fossils and associated implements are not older and *on geological grounds must be dated as early Gamblian.*

Climatic Change. As stated above, the evidence of climatic change should not as yet be made to yield an absolute age for the deposits in the absence of a standard Pleistocene succession for this region; the palaeoclimatic sequence is, however, entirely compatible with an early Gamblian dating.

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* The views attributed to Mr. Keith Jolly in this paragraph are based on personal communication.

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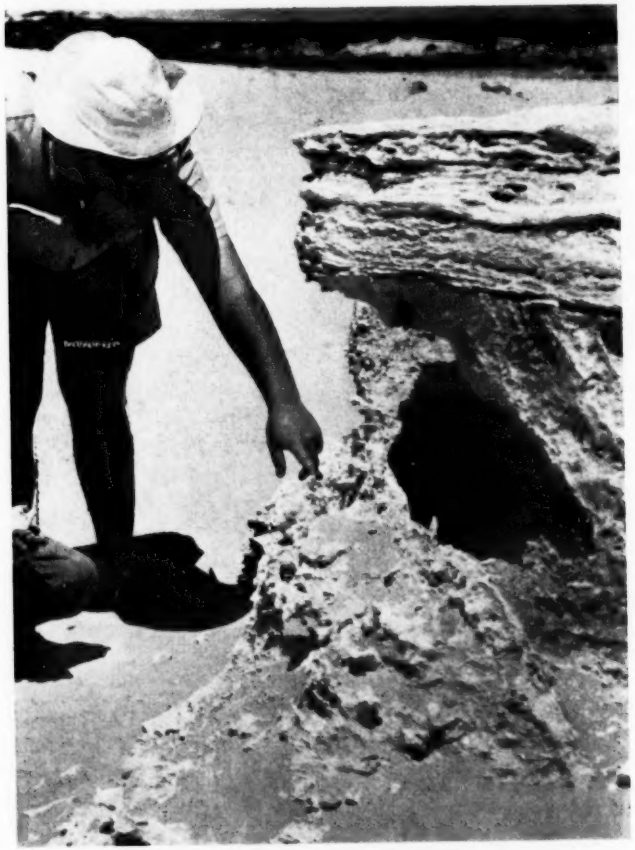
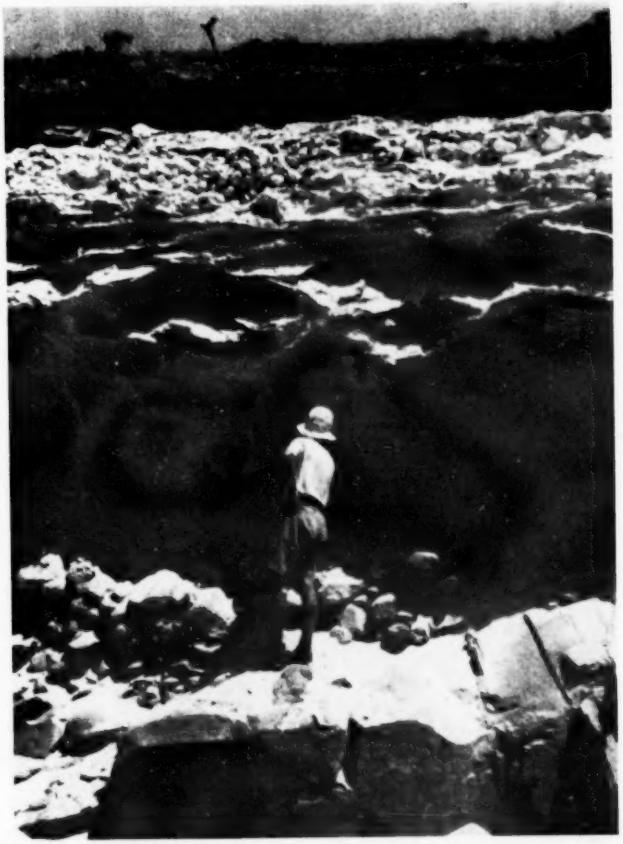


(A) White calcareous dune sands with slip bedding capped by a layered calcrete at the northern end of the limestone dune ridge, Main Site. Fossil bone is embedded in the sands immediately below the capping (top left). *Photo by Cape Argus*



(B) Calcreted sands of the Dorcasia Limestone Formation overlying the 20–25 ft. (6–8 m.) raised beach at Yzerfontein. *Photo by R. Singer*

(A) Sinuous ferricrete ridge in the south-eastern part of Main Site, with nodular calcrete of fossiliferous horizon in the foreground. The section illustrated in figure 10 was taken on the flank of the ridge, below the survey peg. *Photo by R. Singer*

(B) Ferricrete ridges at 16 ft. (5 m.) above sea-level on the Atlantic shore at Bok Baai. Their resemblance to those at Hopefield is striking, and artefacts comparable with the Hopefield assemblage have been discovered on their surfaces. *Photo by J. A. Mabbutt*

(A) Fossil bones capping a low mound of nodular calcrete and sand in Homo Bay, Main Site.
Photo by H. S. Jager

(B) Details of the fossiliferous horizon, showing fossil bone and a hand-axe eroding out from white nodular calcrete.
Photo by R. Singer

(A) Dark ferruginous sands overlying the nodular fossiliferous horizon in the east of Main Site.
Photo by P. M. Hobson

(B) Hand-axes, cleavers, discoidal cores and fabricators from Hopefield, showing a typical range of materials, including fine and coarse-grained silcrete, darker coloured quartzite and quartz-porphyry (right centre).
Photo by G. McManus